

THE SEIBERG-WITTEN EQUATIONS  
AND APPLICATIONS TO THE  
TOPOLOGY OF SMOOTH  
FOUR-MANIFOLDS

BY

JOHN W. MORGAN

MATHEMATICAL NOTES

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# Seiberg Witten Equations And Applications To The Topology Of Smooth Four Manifolds

**John W. Morgan**



## **Seiberg Witten Equations And Applications To The Topology Of Smooth Four Manifolds:**

The Seiberg-Witten Equations and Applications to the Topology of Smooth Four-Manifolds John W. Morgan, 2014-09-08

The recent introduction of the Seiberg Witten invariants of smooth four manifolds has revolutionized the study of those manifolds. The invariants are gauge theoretic in nature and are close cousins of the much studied SU 2 invariants defined over fifteen years ago by Donaldson. On a practical level the new invariants have proved to be more powerful and have led to a vast generalization of earlier results. This book is an introduction to the Seiberg Witten invariants. The work begins with a review of the classical material on Spin  $c$  structures and their associated Dirac operators. Next comes a discussion of the Seiberg Witten equations which is set in the context of nonlinear elliptic operators on an appropriate infinite dimensional space of configurations. It is demonstrated that the space of solutions to these equations called the Seiberg Witten moduli space is finite dimensional and its dimension is then computed. In contrast to the SU 2 case the Seiberg Witten moduli spaces are shown to be compact. The Seiberg Witten invariant is then essentially the homology class in the space of configurations represented by the Seiberg Witten moduli space. The last chapter gives a flavor for the applications of these new invariants by computing the invariants for most Kähler surfaces and then deriving some basic topological consequences for these surfaces.

*Lectures on Seiberg-Witten Invariants* John D. Moore, 2001-04-24. Riemannian symplectic and complex geometry are often studied by means of solutions to systems of nonlinear differential equations such as the equations of geodesics, minimal surfaces, pseudoholomorphic curves and Yang Mills connections. For studying such equations a new unified technology has been developed involving analysis on infinite dimensional manifolds. A striking application of the new technology is Donaldson's theory of anti self dual connections on SU 2 bundles over four manifolds which applies the Yang Mills equations from mathematical physics to shed light on the relationship between the classification of topological and smooth four manifolds. This reverses the expected direction of application from topology to differential equations to mathematical physics. Even though the Yang Mills equations are only mildly nonlinear a prodigious amount of nonlinear analysis is necessary to fully understand the properties of the space of solutions. At our present state of knowledge understanding smooth structures on topological four manifolds seems to require nonlinear as opposed to linear PDE's. It is therefore quite surprising that there is a set of PDE's which are even less nonlinear than the Yang Mills equation but can yield many of the most important results from Donaldson's theory. These are the Seiberg Witten equations. These lecture notes stem from a graduate course given at the University of California in Santa Barbara during the spring quarter of 1995. The objective was to make the Seiberg Witten approach to Donaldson theory accessible to second year graduate students who had already taken basic courses in differential geometry and algebraic topology.

*Geometry and Topology of Manifolds* Hans U. Boden, This book contains expository papers that give an up to date account of recent developments and open problems in the geometry and topology of manifolds along with several research articles that present new results appearing

in published form for the first time. The unifying theme is the problem of understanding manifolds in low dimensions notably in dimensions three and four and the techniques include algebraic topology surgery theory Donaldson and Seiberg Witten gauge theory Heegaard Floer homology contact and symplectic geometry and Gromov Witten invariants. The articles collected for this volume were contributed by participants of the Conference Geometry and Topology of Manifolds held at McMaster University on May 14-18 2004 and are representative of the many excellent talks delivered at the conference.

*Gauge Theory and the Topology of Four-Manifolds* Robert Friedman, John W. Morgan, 2004-12-05. 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.

**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, 1999-12-15. *Lectures on Seiberg-Witten Invariants* John D. Moore, 2009-01-20. Riemannian symplectic and complex geometry are often studied by means of solutions to systems of nonlinear differential equations such as the equations of geodesics minimal surfaces pseudoholomorphic curves and Yang-Mills connections. For studying such equations a new unified technology has been developed involving analysis on infinite dimensional manifolds. A striking application of the new technology is Donaldson's theory of anti-self dual connections on SU(2) bundles over four manifolds which applies the Yang

Mills equations from mathematical physics to shed light on the relationship between the classification of topological and smooth four manifolds This reverses the expected direction of application from topology to differential equations to mathematical physics Even though the Yang Mills equations are only mildly nonlinear a prodigious amount of nonlinear analysis is necessary to fully understand the properties of the space of solutions At our present state of knowledge understanding smooth structures on topological four manifolds seems to require nonlinear as opposed to linear PDE s It is therefore quite surprising that there is a set of PDE s which are even less nonlinear than the Yang Mills equation but can yield many of the most important results from Donaldson s theory These are the Seiberg Witte equations These lecture notes stem from a graduate course given at the University of California in Santa Barbara during the spring quarter of 1995 The objective was to make the Seiberg Witten approach to Donaldson theory accessible to second year graduate students who had already taken basic courses in differential geometry and algebraic topology **Geometry in History** S. G.

Dani,Athanase Papadopoulos,2019-10-18 This is a collection of surveys on important mathematical ideas their origin their evolution and their impact in current research The authors are mathematicians who are leading experts in their fields The book is addressed to all mathematicians from undergraduate students to senior researchers regardless of the specialty

**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 *Geometry and Physics* H. Pedersen,2021-01-07 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

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