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The generalized Lichnerowicz formula and analysis of Dirac operators

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Abstract. We study Dirac operators acting on sections of a Clifford module $\mathcal{E}$ over a Riemannian manifold M. We prove the intrinsic decomposition formula for their square, which is the generalisation of the well-known formula due to Lichnerowicz [L]. This formula enables us to distinguish Dirac operators of simple type. For each Dirac operator of this natural class the local Atiyah-Singer index theorem holds. Furthermore, if M is compact and $\dim M = 2n \geq 4$, we derive an expression for the Wodzicki function $W_{\mathcal{E}}$, which is defined via the non-commutative residue on the space of all Dirac operators $\mathcal{D}(\mathcal{E})$. We calculate this function for certain Dirac operators explicitly. From a physical point of view this provides a method to derive gravity, resp. combined gravity/Yang-Mills actions from the Dirac operators in question.

Keywords: *Lichnerowicz formula, Dirac operator, Wodzicki function, gauge theory*

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Dirac Operators In Analysis

Andreas Rosén

Dirac Operators In Analysis:

Dirac Operators in Analysis John Ryan,Daniele C Struppa,1999-01-06 Clifford analysis has blossomed into an increasingly relevant and fashionable area of research in mathematical analysis it fits conveniently at the crossroads of many fundamental areas of research including classical harmonic analysis operator theory and boundary behavior This book presents a state of the art account of the most recent developments in the field of Clifford analysis with contributions by many of the field s leading researchers Dirac Operators in Riemannian Geometry Thomas Friedrich,2000 For a Riemannian manifold M the geometry topology and analysis are interrelated in ways that have become widely explored in modern mathematics Bounds on the curvature can have significant implications for the topology of the manifold The eigenvalues of the Laplacian are naturally linked to the geometry of the manifold For manifolds that admit spin structures one obtains further information from equations involving Dirac operators and spinor fields In the case of four manifolds for example one has the remarkable Seiberg Witten invariants In this text Friedrich examines the Dirac operator on Riemannian manifolds especially its connection with the underlying geometry and topology of the manifold The presentation includes a review of Clifford algebras spin groups and the spin representation as well as a review of spin structures and textrm spin mathbb C structures With this foundation established the Dirac operator is defined and studied with special attention to the cases of Hermitian manifolds and symmetric spaces Then certain analytic properties are established including self adjointness and the Fredholm property An important link between the geometry and the analysis is provided by estimates for the eigenvalues of the Dirac operator in terms of the scalar curvature and the sectional curvature Considerations of Killing spinors and solutions of the twistor equation on M lead to results about whether M is an Einstein manifold or conformally equivalent to one Finally in an appendix Friedrich gives a concise introduction to the Seiberg Witten invariants which are a powerful tool for the study of four manifolds There is also an appendix reviewing principal bundles and connections This detailed book with elegant proofs is suitable as a text for courses in advanced differential geometry and global analysis and can serve as an introduction for further study in these areas This edition is translated from the German edition published by Vieweg Verlag **Analysis of Dirac Systems and Computational Algebra** Fabrizio Colombo,Irene Sabadini,Franciscus Sommen,Daniele C. Struppa,2004-09-23 The main treatment is devoted to the analysis of systems of linear partial differential equations PDEs with constant coefficients focusing attention on null solutions of Dirac systems All the necessary classical material is initially presented Geared toward graduate students and researchers in hyper complex analysis Clifford analysis systems of PDEs with constant coefficients and mathematical physics *An Introduction to Dirac Operators on Manifolds* Jan Cnops,2012-12-06 Dirac operators play an important role in several domains of mathematics and physics for example index theory elliptic pseudodifferential operators electromagnetism particle physics and the representation theory of Lie groups In this essentially self contained work the basic ideas underlying the concept of Dirac operators are explored Starting

with Clifford algebras and the fundamentals of differential geometry the text focuses on two main properties namely conformal invariance which determines the local behavior of the operator and the unique continuation property dominating its global behavior Spin groups and spinor bundles are covered as well as the relations with their classical counterparts orthogonal groups and Clifford bundles The chapters on Clifford algebras and the fundamentals of differential geometry can be used as an introduction to the above topics and are suitable for senior undergraduate and graduate students The other chapters are also accessible at this level so that this text requires very little previous knowledge of the domains covered The reader will benefit however from some knowledge of complex analysis which gives the simplest example of a Dirac operator More advanced readers mathematical physicists physicists and mathematicians from diverse areas will appreciate the fresh approach to the theory as well as the new results on boundary value theory Clifford Algebras and Dirac Operators in Harmonic Analysis John E. Gilbert,M. Murray,1991-07-26 The aim of this book is to unite the seemingly disparate topics of Clifford algebras analysis on manifolds and harmonic analysis The authors show how algebra geometry and differential equations play a more fundamental role in Euclidean Fourier analysis They then link their presentation of the Euclidean theory naturally to the representation theory of semi simple Lie groups *Dirac Operators and Analysis on Open Manifolds* Gorm Salomonsen,1996 *Dirac Operators and Clifford Analysis on Manifolds with Boundary* David M. J. Calderbank,1997

Dirac Operators and Spectral Geometry Giampiero Esposito,1998-08-20 A clear concise and up to date introduction to the theory of the Dirac operator and its wide range of applications in theoretical physics for graduate students and researchers

Analysis of Dirac Operators on Some Conformally Flat Manifolds John Ryan,Rolf Soeren Krausshar,2006 Riesz Transforms, Hodge-Dirac Operators and Functional Calculus for Multipliers Cédric Arhancet,Christoph Kriegler,2022-05-05 This book on recent research in noncommutative harmonic analysis treats the Lp boundedness of Riesz transforms associated with Markovian semigroups of either Fourier multipliers on non abelian groups or Schur multipliers The detailed study of these objects is then continued with a proof of the boundedness of the holomorphic functional calculus for Hodge Dirac operators thereby answering a question of Junge Mei and Parcet and presenting a new functional analytic approach which makes it possible to further explore the connection with noncommutative geometry These Lp operations are then shown to yield new examples of quantum compact metric spaces and spectral triples The theory described in this book has at its foundation one of the great discoveries in analysis of the twentieth century the continuity of the Hilbert and Riesz transforms on Lp In the works of Lust Piquard 1998 and Junge Mei and Parcet 2018 it became apparent that these Lp operations can be formulated on Lp spaces associated with groups Continuing these lines of research the book provides a self contained introduction to the requisite noncommutative background Covering an active and exciting topic which has numerous connections with recent developments in noncommutative harmonic analysis the book will be of interest both to experts in no commutative Lp spaces and analysts interested in the construction of Riesz transforms and Hodge Dirac operators

Clifford Analysis ,2007 *Geometric Multivector Analysis* Andreas Rosén,2019-11-09 This book presents a step by step guide to the basic theory of multivectors and spinors with a focus on conveying to the reader the geometric understanding of these abstract objects Following in the footsteps of M Riesz and L Ahlfors the book also explains how Clifford algebra offers the ideal tool for studying spacetime isometries and M bius maps in arbitrary dimensions The book carefully develops the basic calculus of multivector fields and differential forms and highlights novelties in the treatment of e g pullbacks and Stokes s theorem as compared to standard literature It touches on recent research areas in analysis and explains how the function spaces of multivector fields are split into complementary subspaces by the natural first order differential operators e g Hodge splittings and Hardy splittings Much of the analysis is done on bounded domains in Euclidean space with a focus on analysis at the boundary The book also includes a derivation of new Dirac integral equations for solving Maxwell scattering problems which hold promise for future numerical applications The last section presents down to earth proofs of index theorems for Dirac operators on compact manifolds one of the most celebrated achievements of 20th century mathematics The book is primarily intended for graduate and PhD students of mathematics It is also recommended for more advanced undergraduate students as well as researchers in mathematics interested in an introduction to geometric analysis

Spectral Analysis of Dirac Operators Under Integral Conditions on the Potential Daniel Gordon John Hughes,2012

Dirac Operators, Heat Kernels and Micrrorlocal Analysis Rafe Mazzeo,Paolo Piazza,1997 *Clifford Analysis and Related Topics* Paula Cerejeiras,Craig A. Nolder,John Ryan,Carmen Judith Vanegas Espinoza,2018-09-07 This book intended to commemorate the work of Paul Dirac highlights new developments in the main directions of Clifford analysis Just as complex analysis is based on the algebra of the complex numbers Clifford analysis is based on the geometric Clifford algebras Many methods and theorems from complex analysis generalize to higher dimensions in various ways However many new features emerge in the process and much of this work is still in its infancy Some of the leading mathematicians working in this field have contributed to this book in conjunction with Clifford Analysis and Related Topics a conference in honor of Paul A M Dirac which was held at Florida State University Tallahassee on December 15 17 2014 The content reflects talks given at the conference as well as contributions from mathematicians who were invited but were unable to attend Hence much of the mathematics presented here is not only highly topical but also cannot be found elsewhere in print Given its scope the book will be of interest to mathematicians and physicists working in these areas as well as students seeking to catch up on the latest developments *Clifford Analysis for Dirac Operators on Manifolds with Boundary* David M. J. Calderbank,1996 **Clifford Algebra and Spinor-Valued Functions** R. Delanghe,F. Sommen,V. Soucek,2012-12-06 This volume describes the substantial developments in Clifford analysis which have taken place during the last decade and in particular the role of the spin group in the study of null solutions of real and complexified Dirac and Laplace operators The book has six main chapters The first two Chapters 0 and I present classical results on real and complex Clifford algebras and

show how lower dimensional real Clifford algebras are well suited for describing basic geometric notions in Euclidean space Chapters II and III illustrate how Clifford analysis extends and refines the computational tools available in complex analysis in the plane or harmonic analysis in space In Chapter IV the concept of monogenic differential forms is generalized to the case of spin manifolds Chapter V deals with analysis on homogeneous spaces and shows how Clifford analysis may be connected with the Penrose transform The volume concludes with some Appendices which present basic results relating to the algebraic and analytic structures discussed These are made accessible for computational purposes by means of computer algebra programmes written in REDUCE and are contained on an accompanying floppy disk Spectral Analysis of Relativistic Operators A. A. Balinsky,W. D. Evans,2011 Over the last decade there has been considerable interest and progress in determining the spectral properties of various operators that take relativistic effects into account with important implications for mathematics and physics Difficulties are encountered in many particle problems due to the lack of semiboundedness of the Dirac operator and this has led to the investigation of operators like those of Chandrasekhar Herbst and Brown Ravenhall which are semibounded under appropriate circumstances This book contains an up to date comprehensive and self contained analysis of the spectral properties of these operators providing the tools for anyone working in this area Another major feature is the work of the authors on zero modes a topic which has important significance for the stability of matter and other physical problems Up until now these topics have been scattered throughout the literature without a systematic and cohesive treatment The book will report largely on the progress on these topics published since 1992 *Dirac Operators in Representation Theory* Jing-Song Huang,Pavle Pandzic,2007-05-27 This monograph presents a comprehensive treatment of important new ideas on Dirac operators and Dirac cohomology Dirac operators are widely used in physics differential geometry and group theoretic settings particularly the geometric construction of discrete series representations The related concept of Dirac cohomology which is defined using Dirac operators is a far reaching generalization that connects index theory in differential geometry to representation theory Using Dirac operators as a unifying theme the authors demonstrate how some of the most important results in representation theory fit together when viewed from this perspective An excellent contribution to the mathematical literature of representation theory this self contained exposition offers a systematic examination and panoramic view of the subject The material will be of interest to researchers and graduate students in representation theory differential geometry and physics **Elliptic Boundary Problems for Dirac Operators** Bernhelm Booss,Krzysztof P. Wojciechhowski,1993-12 Elliptic boundary problems have enjoyed interest recently espe cially among C algebraists and mathematical physicists who want to understand single aspects of the theory such as the behaviour of Dirac operators and their solution spaces in the case of a non trivial boundary However the theory of elliptic boundary problems by far has not achieved the same status as the theory of elliptic operators on closed compact without boundary manifolds The latter is nowadays rec ognized by many as a mathematical work of art

and a very useful technical tool with applications to a multitude of mathematical con texts Therefore the theory of elliptic operators on closed manifolds is well known not only to a small group of specialists in partial dif ferential equations but also to a broad range of researchers who have specialized in other mathematical topics Why is the theory of elliptic boundary problems compared to that on closed manifolds still lagging behind in popularity Admittedly from an analytical point of view it is a jigsaw puzzle which has more pieces than does the elliptic theory on closed manifolds But that is not the only reason

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