Multivectors And Clifford Algebra In Electrodynamics

Matrix algebra has been called "the arithmetic of higher mathematics" [Be]. We think the basis for a better arithmetic has long been available, but its versatility has hardly been appreciated, and it has not yet been integrated into the mainstream of mathematics. We refer to the system commonly called 'Clifford Algebra', though we prefer the name 'Geometric Algebm' suggested by Clifford himself. Many distinct algebraic systems have been adapted or developed to express geometric relations and describe geometric structures. Especially notable are those algebras which have been used for this purpose in physics, in particular, the system of complex numbers, the quatemions, matrix algebra, vector, tensor and spinor algebras and the algebra of differential forms. Each of these geometric algebras has some significant advantage over the others in certain applications, so no one of them provides an adequate algebraic structure for all purposes of geometry and physics. At the same time, the algebras overlap considerably, so they provide several different mathematical representations for individual geometrical or physical ideas.

The use of Clifford algebras in mathematical physics and engineering has grown rapidly in recent years. Whereas other developments have privileged a geometric approach, this book uses an algebraic approach that can be introduced as a tensor product of quaternion algebras and provides a unified calculus for much of physics. It proposes a pedagogical introduction to this new calculus, based on quaternions, with applications mainly in special relativity, classical electromagnetism, and general relativity.

This book presents a broad overview of the theory and applications of structure topology and symplectic geometry. Over six chapters, the authors cover topics such as linear operators, Omega and Clifford algebra, and quasiconformal reflection across polygonal lines. The book also includes four interesting case studies on time series analysis in practice. Finally, it provides a snapshot of some current trends and future challenges in the research of symplectic geometry theory. Structure Topology and Symplectic Geometry is a resource for scholars, researchers, and teachers in the field of mathematics, as well as researchers and students in engineering.

This concise classic presents advanced undergraduates and graduate students in mathematics with an overview of geometric algebra. The text originated with lecture notes from a New York University course taught by Emil Artin, one of the preeminent mathematicians of the twentieth century. The Bulletin of the American Mathematical Society praised Geometric Algebra upon its initial publication, noting that "mathematicians will find on many pages ample evidence of the author's ability to penetrate a subject and to present material in a particularly elegant manner." Chapter 1 serves as reference, consisting of the proofs of certain isolated algebraic theorems. Subsequent chapters explore affine and projective geometry, symplectic and orthogonal geometry, the general linear group, and the structure of symplectic and orthogonal groups. The author offers suggestions for the use of this book, which concludes with a bibliography and index.

This edited survey book consists of 20 chapters showing application of Clifford algebra in quantum mechanics, field theory, spinor calculations, projective geometry, Hypercomplex algebra, function theory and crystallography. Many examples of computations performed with a variety of readily available software programs are presented in detail.

The subject of Clifford (geometric) algebras offers a unified algebraic framework for the direct expression of the geometric concepts in algebra, geometry, and physics. This bird's-eye view of the discipline is presented by six of the world's leading experts in the field; it features an introductory chapter on Clifford algebras, followed by extensive explorations of their applications to physics, computer science, and differential geometry. The book is ideal for graduate students in mathematics, physics, and computer science; it is appropriate both for newcomers who have little prior knowledge of the field and professionals who wish to keep abreast of the latest applications.

Central to the work is the classification of the conjugation and reversion anti-involutions that arise naturally in the theory. It is of interest that all the classical groups play essential roles in this classification. Other features include detailed sections on conformal groups, the eight-dimensional non-associative Cayley algebra, its automorphism group, the exceptional Lie group G[subscript 2], and the triality automorphism of Spin 8.

This monograph-like anthology introduces the concepts and framework of Clifford algebra. It provides a rich source of examples of how to work with this formalism. Clifford or geometric algebra shows strong unifying aspects and turned out in the 1960s to be a most adequate formalism for describing different geometry-related algebraic systems as specializations of one "mother algebra" in various subfields of physics and engineering. Recent work shows that Clifford algebra provides a universal and powerful algebraic framework for an elegant and coherent representation of various problems occurring in computer science, signal processing, neural computing, image processing, pattern recognition, computer vision, and robotics.

This book aims to disseminate geometric algebra as a straightforward mathematical tool set for working with and understanding classical electromagnetic theory. It's target readership is anyone who has some knowledge of electromagnetic theory, predominantly ordinary scientists and engineers who use it in the course of their work, or postgraduate students and senior undergraduates who are seeking to broaden their knowledge and increase their understanding of the subject. It is assumed that the reader is not a mathematical specialist and is neither familiar with geometric algebra or its application to electromagnetic theory. The modern approach, geometric algebra, is the mathematical tool set we should all have started out with and once the reader has a grasp of the subject, he or she cannot fail to realize that traditional vector analysis is really awkward and even misleading by comparison. Professors can request a solutions manual by email: pressbooks@ieee.org

Geometric algebra has established itself as a powerful and valuable mathematical tool for solving problems in computer science, engineering, physics, and mathematics. The articles in this volume, written by experts in various fields, reflect an interdisciplinary approach to the subject, and highlight a range of techniques and applications. Relevant ideas are introduced in a self-contained manner and only a knowledge of linear algebra and calculus is assumed. Features and Topics: * The mathematical foundations of geometric algebra are explored * Applications in computational geometry include models of reflection and ray-tracing and a new and concise characterization of the crystallographic groups * Applications in engineering include robotics, image geometry, control-pose estimation, inverse kinematics and dynamics, control and visual navigation * Applications in physics include rigid-body dynamics, elasticity, and electromagnetism * Chapters dedicated to quantum information theory dealing with multi- particle entanglement, MRI, and relativistic generalizations Practitioners, professionals, and researchers working in computer science, engineering, physics, and mathematics will find a wide range of useful applications in this state-of-the-art survey and reference book. Additionally, advanced graduate students interested in geometric algebra will find the most current applications and methods discussed.

(revised) This is a textbook on classical mechanics at the intermediate level, but its main purpose is to serve as an introduction to a new mathematical language for physics called geometric algebra. Mechanics is most commonly formulated today in terms of the vector algebra developed by the American physicist J. Willard Gibbs, but for some applications of mechanics the algebra of complex numbers is more efficient than vector algebra, while in other applications matrix algebra works better. Geometric algebra integrates all these algebraic systems into a coherent mathematical language which not only retains the advantages of each special algebra but possesses powerful new capabilities. This book covers the fairly standard material for a course on the mechanics of particles and rigid bodies. However, it will be seen that geometric algebra brings new insights into the treatment of nearly every topic and produces simplifications that move the subject quickly to advanced levels. That has made it possible in this book to carry the treatment of two major topics in mechanics well beyond the level of other textbooks. A few words are in order about the unique treatment of these two topics, namely, rotational dynamics and celestial mechanics.

This volume contains selected papers presented at the Second Workshop on Clifford Algebras and their Applications in Mathematical Physics. These papers range from various algebraic and analytic aspects of Clifford algebras to applications in, for example, gauge fields, relativity theory, supersymmetry and supergravity, and condensed phase physics. Included is a biography and list of publications of Mário Schenberg, who, next to Marcel Riesz, has made valuable contributions to these topics. This volume will be of interest to mathematicians working in the fields of algebra, geometry or special functions, to physicists working on quantum mechanics or supersymmetry, and to historians of mathematical physics.

This book introduces the fundamentals of geometric algebra and calculus, and applies those tools to the study of electromagnetism. Geometric algebra provides a structure that can represent oriented point, line, plane, and volume segments. Vectors, which can be thought of as a representation of oriented line segments, are generalized to multivectors. A full fledged, but non-commutative (i.e. order matters) mul- tiplication operation will be defined for products of vectors. Namely, the square of a vector is the square of its length. This simple rule, along with a requirement that we can sum vectors and their products, essentially defines geometric algebra. Such sums of scalars, vectors and vector products are called multivectors. The reader will see that familiar concepts such as the dot and cross product are related to a more general vector product, and that algebraic structures such as complex numbers can be represented as multivectors. We will be able to utilize generalized complex exponentials to do rotations in arbitrarily oriented planes in space, and will find that simple geometric algebra representations of many geometric transformations are possible. Generalizations of the divergence and Stokes' theorems are required once we choose to work with multivector functions. There is an unfortunate learning curve required to express this gen- eralization, but once overcome, we will be left with a single powerful multivector integration theorem that has no analogue in conventional vector calculus. This fundamental theorem of geo- metric calculus incorporates Green's (area) theorem, the divergence theorem, Stokes' theorems, and complex residue calculus. Multivector calculus also provides the opportunity to define a few unique and powerful Green's functions that almost trivialize solutions of Maxwell's equations. Instead of working separately with electric and magnetic fields, we will work with a hybrid multivector field that includes both electric and magnetic field contributions, and with a mul- tivector current that includes both charge and current densities. The natural representation of Maxwell's equations is a single multivector equation that is easier to solve and manipulate then the conventional mess of divergence and curl equations are familiar to the reader. This book is aimed at graduate or advanced undergraduates in electrical engineering or physics. While all the fundamental results of electromagnetism are derived from Maxwell's equations, there will be no attempt to motivate Maxwell's equations themselves, so existing familiarity with the subject is desirable.

The goal of the Volume I Geometric Algebra for Computer Vision, Graphics and Neural Computing is to present a unified mathematical treatment of diverse problems in the general domain of artificial intelligence and associated fields using Clifford, or geometric, algebra. Geometric algebra provides a rich and general mathematical framework for Geometric Cybernetics in order to develop solutions, concepts and computer algorithms without losing geometric insight of the problem in question. Current mathematical subjects can be treated in an unified manner without abandoning the mathematical system of geometric algebra for instance: multilinear algebra, projective and affine geometry, calculus on manifolds, Riemann geometry, the representation of Lie algebras and Lie groups using bivector algebras and conformal geometry. By treating a wide spectrum of problems in a common language, this Volume I offers both new insights and new solutions that should be useful to scientists, and engineers working in different areas related with the development and building of intelligent machines. Each chapter is written in accessible terms accompanied by numerous examples, figures and a complementary appendix on Clifford algebras, all to clarify the theory and the crucial aspects of the application of geometric algebra to problems in graphics engineering, image processing, pattern recognition, computer vision, machine learning, neural computing and cognitive systems.

The plausible relativistic physical variables describing a spinning, charged and massive particle are, besides the charge itself, its Minkowski (four) po sition X, its relativistic linear (four) momentum P and also its so-called Lorentz (four) angular momentum E # 0, the latter forming four trans lation invariant part of its total angular (four) momentum M. Expressing these variables in terms of Poincare covariant real valued functions defined on an extended relativistic phase space [2, 7J means that the mutual Pois son bracket relations among the total angular momentum functions Mab and the linear momentum functions pa have to represent the commutation relations of the Poincare algebra. On any such an extended relativistic phase space, as shown by Zakrzewski [2, 7], the (natural?) Poisson bracket relations (1. 1) imply that for the splitting of the total angular momentum into its orbital and its spin part (1. 2) one necessarily obtains (1. 3) On the other hand it is always possible to shift (translate) the commuting (see (1. 1)) four position xa by a four vector ~Xa (1. 4) so that the total angular four momentum splits instead into a new orbital and a new (Pauli-Lubanski) spin part (1. 5) in such a way that (1. 6) However, as proved by Zakrzewski [2, 7J, the so-defined new shifted four a position functions X must fulfill the following Poisson bracket relations: (1.

This text explores how Clifford algebras and spinors have been sparking a collaboration and bridging a gap between Physics and Mathematics. This collaboration has been the consequence of a growing awareness of the importance of algebraic and geometric properties in many physical phenomena, and of the discovery of common ground through various touch points: relating Clifford algebras and the arising geometry to so-called spinors, and to their three definitions (both from the mathematical and physical viewpoint). The main point of contact are the representations of Clifford algebras and the periodicity theorems. Clifford algebras also constitute a highly intuitive formalism, having an intimate relationship to quantum field theory. The text strives to seamlessly combine these various viewpoints and is devoted to a wider audience of both physicists and mathematicians. Among the existing approaches to Clifford algebras and spinors this book is unique in that it provides a didactical presentation of the topic and is accessible to both students and researchers. It emphasizes the formal character and the deep algebraic and geometric completeness, and merges them with the physical applications. The style is clear and precise, but not pedantic. The sole pre-requisites is a course in Linear Algebra which most students of Physics, Mathematics or Engineering will have covered as part of their undergraduate studies.

This highly practical Guide to Geometric Algebra in Practice reviews algebraic techniques for geometrical problems in computer science and engineering, and the relationships between them. The topics covered range from powerful new theoretical developments, to successful applications, and the development of new software and hardware tools. Topics and features: provides hands-on review exercises throughout the book, together with helpful chapter summaries; presents a concise introductory tutorial to conformal geometric algebra (CGA) in the appendices; examines the application of CGA for the description of rigid body motion, interpolation and tracking, and image processing; reviews the employment of GA in theorem proving and combinatorics; discusses the geometric algebra of lines, lower-dimensional algebras, and other alternatives to 5-dimensional CGA; proposes applications of coordinate-free methods of GA for differential geometry.

Bringing geometric algebra to the mainstream of physics pedagogy, Geometric Algebra and Applications to Physics not only presents geometric algebra as a discipline within mathematical physics, but the book also shows how geometric algebra can be applied to numerous fundamental problems in physics, especially in experimental situations. This

This volume is a collection of research surveys on the Distance Geometry Problem (DGP) and its applications. It will be divided into three parts: Theory, Methods and Applications. Each part will contain at least one survey and several research papers. The first part, Theory, will deal with theoretical aspects of the DGP, including a new class of problems and the study of its complexities as well as the relation between DGP and other related topics, such as: distance matrix theory, Euclidean distance matrix completion problem, multispherical structure of distance matrices, distance geometry and geometric algebra, algebraic distance geometry theory, visualization of K-dimensional structures in the plane, graph rigidity, and theory of discretizable DGP: symmetry and complexity. The second part, Methods, will discuss mathematical and computational properties of methods developed to the problems considered in the first chapter including continuous methods (based on Gaussian and hyperbolic smoothing, difference of convex functions, semidefinite programming, branch-and-bound), discrete methods (based on branch-and-prune, geometric build-up, graph rigidity), and also heuristics methods (based on simulated annealing, genetic algorithms, tabu search, variable neighborhood search). Applications will comprise the third part and will consider applications of DGP to NMR structure calculation, rational drug design, molecular dynamics simulations, graph drawing and sensor network localization. This volume will be the first edited book on distance geometry and applications. The editors are in correspondence with the major contributors to the field of distance geometry, including important research centers in molecular biology such as Institut Pasteur in Paris.

Differential geometry is the study of the curvature and calculus of curves and surfaces. A New Approach to Differential Geometry using Clifford's Geometric Algebra simplifies the discussion to an accessible level of differential geometry by introducing Clifford algebra. This presentation is relevant because Clifford algebra is an effective tool for dealing with the rotations intrinsic to the study of curved space. Complete with chapter-by-chapter exercises, an overview of general relativity, and brief biographies of historical figures, this comprehensive textbook presents a valuable introduction to differential geometry. It will serve as a useful resource for upper-level undergraduates, beginning-level graduate students, and researchers in the algebra and physics communities.

Understanding Geometric Algebra: Hamilton, Grassmann, and Clifford for Computer Vision and Graphics introduces geometric algebra with an emphasis on the background mathematics of Hamilton, Grassmann, and Clifford. It shows how to describe and compute geometry for 3D modeling applications in computer graphics and computer vision.Unlike similar texts

This new book contains the most up-to-date and focused description of the applications of Clifford algebras in analysis, particularly classical harmonic analysis. It is the first single volume devoted to applications of Clifford analysis to other aspects of analysis. All chapters are written by world authorities in the area. Of particular interest is the contribution of Professor Alan McIntosh. He gives a detailed account of the links between Clifford algebras, monogenic and harmonic functions and the correspondence between monogenic functions and holomorphic functions of several complex variables under Fourier transforms. He describes the correspondence between algebras of singular integrals on Lipschitz surfaces and functional calculi of Dirac operators on these surfaces. He also discusses links with boundary value problems over Lipschitz domains. Other specific topics include Hardy spaces and compensated compactness in Euclidean space; applications to acoustic scattering and Galerkin estimates; scattering theory for orthogonal wavelets; applications of the conformal group and Vahalen matrices; Newmann type problems for the Dirac operator; plus much, much more! Clifford Algebras in Analysis and Related Topics also contains the most comprehensive section on open problems available. The book presents the most detailed link between Clifford analysis and classical harmonic analysis. It is a refreshing break from the many expensive and lengthy volumes currently found on the subject.

Geometric algebra is a powerful mathematical language with applications across a range of subjects in physics and engineering. This book is a complete guide to the current state of the subject with early chapters providing a self-contained introduction to geometric algebra. Topics covered include new techniques for handling rotations in arbitrary dimensions, and the links between rotations, bivectors and the structure of the Lie groups. Following chapters extend the concept of a complex analytic function theory to arbitrary dimensions, with applications in quantum theory and electromagnetism. Later chapters cover advanced topics such as non-Euclidean geometry, quantum entanglement, and gauge theories. Applications such as black holes and cosmic strings are also explored. It can be used as a graduate text for courses on the physical applications of geometric algebra and is also suitable for researchers working in the fields of relativity and quantum theory.

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 Möbius 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.

This useful text offers new insights and solutions for the development of theorems, algorithms and advanced methods for real-time applications across a range of disciplines. Its accessible style is enhanced by examples, figures and experimental analysis.

The invited papers in this volume provide a detailed examination of Clifford algebras and their significance to analysis, geometry, mathematical structures, physics, and applications in engineering. While the papers collected in this volume require that the reader possess a solid knowledge of appropriate background material, they lead to the most current research topics. With its wide range of topics, well-established contributors, and excellent references and index, this book will appeal to graduate students and researchers.

The goal of this book is to present a unified mathematical treatment of diverse problems in mathematics, physics, computer science, and engineer ing using geometric algebra. Geometric algebra was invented by William Kingdon Clifford in 1878 as a unification and generalization of the works of Grassmann and Hamilton, which came more than a quarter of a century before. Whereas the algebras of Clifford and Grassmann are well known in advanced mathematics and physics, they have never made an impact in elementary textbooks where the vector algebra of Gibbs-Heaviside still predominates. The approach to Clifford algebra adopted in most of the ar ticles here was pioneered in the 1960s by David Hestenes. Later, together with Garret Sobczyk, he developed it into a unified language for math ematics and physics. Sobczyk first learned about the power of geometric algebra in classes in electrodynamics and relativity taught by Hestenes at Arizona State University from 1966 to 1967. He still vividly remembers a feeling of disbelief that the fundamental geometric product of vectors could have been left out of his undergraduate mathematics education. Geometric algebra provides a rich, general mathematical framework for the develop ment of multilinear algebra, projective and affine geometry, calculus on a manifold, the representation of Lie groups and Lie algebras, the use of the horosphere and many other areas. This book is addressed to a broad audience of applied mathematicians, physicists, computer scientists, and engineers.

Until recently, almost all of the interactions between objects in virtual 3D worlds have been based on calculations performed using linear algebra. Linear algebra relies heavily on coordinates, however, which can make many geometric programming tasks very specific and complex-often a lot of effort is required to bring about even modest performance enhancements. Although linear algebra is an efficient way to specify low-level computations, it is not a suitable high-level language for geometric programming. Geometric Algebra for Computer Science presents a compelling alternative to the limitations of linear algebra. Geometric algebra, or GA, is a compact, time-effective, and performance-enhancing way to represent the geometry of 3D objects in computer programs. In this book you will find an introduction to GA that will give you a strong grasp of its relationship to linear algebra and its significance for your work. You will learn how to use GA to represent objects and perform geometric operations on them. And you will begin mastering proven techniques for making GA an integral part of your applications in a way that simplifies your code without slowing it down. * The first book on Geometric Algebra for programmers in computer graphics and entertainment computing * Written by leaders in the field providing essential information on this new technique for 3D graphics * This full colour book includes a website with GAViewer, a program to experiment with GA

This volume is dedicated to the memory of Albert Crumeyrolle, who died on June 17, 1992. In organizing the volume we gave priority to: articles summarizing Crumeyrolle's own work in differential geometry, general relativity and spinors, articles which give the reader an idea of the depth and breadth of Crumeyrolle's research interests and influence in the field, articles of high scientific quality which would be of general interest. In each of the areas to which Crumeyrolle made significant contribution - Clifford and exterior algebras, Weyl and pure spinors, spin structures on manifolds, principle of triality, conformal geometry - there has been substantial progress. Our hope is that the volume conveys the originality of Crumeyrolle's own work, the continuing vitality of the field he influenced, and the enduring respect for, and tribute to, him and his accomplishments in the mathematical community. It isour pleasure to thank Peter Morgan, Artibano Micali, Joseph Grifone, Marie Crumeyrolle and Kluwer Academic Publishers for their help in preparingthis volume.

Geometric algebra (a Clifford Algebra) has been applied to different branches of physics for a long time but is now being adopted by the computer graphics community and is providing exciting new ways of solving 3D geometric problems. The author tackles this complex subject with inimitable style, and provides an accessible and very readable introduction. The book is filled with lots of clear examples and is very well illustrated. Introductory chapters look at algebraic axioms, vector algebra and geometric conventions and the book closes with a chapter on how the algebra is applied to computer graphics.

Clifford algebras are assuming now an increasing role in theoretical physics. Some of them predominantly larger ones are used in elementary particle theory, especially for a unification of the fundamental interactions. The smaller ones are promoted in more classical domains. This book is intended to demonstrate usefulness of Clifford algebras in classical electrodynamics. Written with a pedagogical aim, it begins with an introductory chapter devoted to multivectors and Clifford algebra for the three-dimensional space. In a later chapter modifications are presented necessary for higher dimension and for the pseudoeuclidean metric of the Minkowski space. Among other advantages one is worth mentioning: Due to a bivectorial description of the magnetic field a notion of force surfaces naturally emerges, which reveals an intimate link between the magnetic field and the electric currents as its sources. Because of the elementary level of presentation, this book can be treated as an introductory course to electromagnetic theory. Numerous illustrations are helpful in visualizing the exposition. Furthermore, each chapter ends with a list of problems which amplify or further illustrate the fundamental arguments. Contents:Mathematical PreliminariesElectromagnetic FieldElectromagnetic PotentialsCharges in the Electromagnetic FieldPlane Electromagnetic FieldsVarious Kinds of Electromagnetic WavesSpecial RelativityRelativity and Electrodynamics Readership: Physicists, electrical and electronics engineers. Keywords:Bivector;Trivector;Multivector;Clifford Algebra;Grassmann Algebra;Electrodynamics;Electric Field;Classical Electrodynamics;Electromagnetic Field;Magnetic Field;Maxwell Equations;Electromagnetic Waves;Lorentz Transformation;Minkowski Space;Relativistic Kinematics;Force Surface

This small book started a profound revolution in the development of mathematical physics, one which has reached many working physicists already, and which stands poised to bring about far-reaching change in the future. At its heart is the use of Clifford algebra to unify otherwise disparate mathematical languages, particularly those of spinors, quaternions, tensors and differential forms. It provides a unified approach covering all these areas and thus leads to a very efficient ‘toolkit’ for use in physical problems including quantum mechanics, classical mechanics, electromagnetism and relativity (both special and general) – only one mathematical system needs to be learned and understood, and one can use it at levels which extend right through to current research topics in each of these areas. These same techniques, in the form of the ‘Geometric Algebra’, can be applied in many areas of engineering, robotics and computer science, with no changes necessary – it is the same underlying mathematics, and enables physicists to understand topics in engineering, and engineers to understand topics in physics (including aspects in frontier areas), in a way which no other single mathematical system could hope to make possible. There is another aspect to Geometric Algebra, which is less tangible, and goes beyond questions of mathematical power and range. This is the remarkable insight it gives to physical problems, and the way it constantly suggests new features of the physics itself, not just the mathematics. Examples of this are peppered throughout ‘Space-Time Algebra’, despite its short length, and some of them are effectively still research topics for the future. From the Foreward by Anthony Lasenby

This International Conference on Clifford AlgebrfU and Their Application, in Math ematical Phy,ic, is the third in a series of conferences on this theme, which started at the Univer,ity of Kent in Canterbury in 1985 and was continued at the Univer,iU de, Science, et Technique, du Languedoc in Montpellier in 1989. Since the start of this series of Conferences the research fields under consideration have evolved quite a lot. The number of scientific papers on Clifford Algebra, Clifford Analysis and their impact on the modelling of physics phenomena have increased tremendously and several new books on these topics were published. We were very pleased to see old friends back and to wellcome new guests who by their inspiring talks contributed fundamentally to tracing new paths for the future development of this research area. The Conference was organized in Deinze, a small rural town in the vicinity of the University town Gent. It was hosted by De Ceder, a vacation and seminar center in a green area, a typical landscape of Flanders's "plat pays" . The Conference was attended by 61 participants coming from 18 countries; there were 10 main talks on invitation, 37 contributions accepted by the Organizing Com mittee and a poster session. There was also a book display of Kluwer Academic Publishers. As in the Proceedings of the Canterbury and Montpellier conferences we have grouped the papers accordingly to the themes they are related to: Clifford Algebra, Clifford Analysis, Classical Mechanics, Mathematical Physics and Physics Models.

This book enables the reader to discover elementary concepts of geometric algebra and its applications with lucid and direct explanations. Why would one want to explore geometric algebra? What if there existed a universal mathematical language that allowed one: to make rotations in any dimension with simple formulas, to see spinors or the Pauli matrices and their products, to solve problems of the special theory of relativity in three-dimensional Euclidean space, to formulate quantum mechanics without the imaginary unit, to easily solve difficult problems of electromagnetism, to treat the Kepler problem with the formulas for a harmonic oscillator, to eliminate unintuitive matrices and tensors, to unite many branches of mathematical physics? What if it were possible to use that same framework to generalize the complex numbers or fractals to any dimension, to play with geometry on a computer, as well as to make calculations in robotics, ray-tracing and brain science? In addition, what if such a language provided a clear, geometric interpretation of mathematical objects, even for the imaginary unit in quantum mechanics? Such a mathematical language exists and it is called geometric algebra. High school students have the potential to explore it, and undergraduate students can master it. The universality, the clear geometric interpretation, the power of generalizations to any dimension, the new insights into known theories, and the possibility of computer implementations make geometric algebra a thrilling field to unearth.

This is the second edition of a popular work offering a unique introduction to Clifford algebras and spinors. The beginning chapters could be read by undergraduates; vectors, complex numbers and quaternions are introduced with an eye on Clifford algebras. The next chapters will also interest physicists, and include treatments of the quantum mechanics of the electron, electromagnetism and special relativity with a flavour of Clifford algebras. This edition has three new chapters, including material on conformal invariance and a history of Clifford algebras.

This volume is an outgrowth of the 1995 Summer School on Theoretical Physics of the Canadian Association of Physicists (CAP), held in Banff, Alberta, in the Canadian Rockies, from July 30 to August 12,1995. The chapters, based on lectures given at the School, are designed to be tutorial in nature, and many include exercises to assist the learning process. Most lecturers gave three or four fifty-minute lectures aimed at relative novices in the field. More emphasis is therefore placed on pedagogy and establishing comprehension than on erudition and superior scholarship. Of course, new and exciting results are presented in applications of Clifford algebras, but in a coherent and user-friendly way to the nonspecialist. The subject area of the volume is Clifford algebra and its applications. Through the geometric language of the Clifford-algebra approach, many concepts in physics are clarified, united, and extended in new and sometimes surprising directions. In particular, the approach eliminates the formal gaps that traditionally separate clas sical, quantum, and relativistic physics. It thereby makes the study of physics more efficient and the research more penetrating, and it suggests resolutions to a major physics problem of the twentieth century, namely how to unite quantum theory and gravity. The term "geometric algebra" was used by Clifford himself, and David Hestenes has suggested its use in order to emphasize its wide applicability, and b& cause the developments by Clifford were themselves based heavily on previous work by Grassmann, Hamilton, Rodrigues, Gauss, and others.

The first part of a two-volume set concerning the field of Clifford (geometric) algebra, this work consists of thematically organized chapters that provide a broad overview of cutting-edge topics in mathematical physics and the physical applications of Clifford algebras. algebras and their applications in physics. Algebraic geometry, cohomology, non-communicative spaces, q-deformations and the related quantum groups, and projective geometry provide the basis for algebraic topics covered. Physical applications and extensions of physical theories such as the theory of quaternionic spin, a projective theory of hadron transformation laws, and electron scattering are also presented, showing the broad applicability of Clifford geometric algebras in solving physical problems. Treatment of the structure theory of quantum Clifford algebras, the connection to logic, group representations, and computational techniques including symbolic calculations and theorem proving rounds out the presentation.

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