

CAUSAL FERMION SYSTEMS

The theory of causal fermion systems represents a novel approach to fundamental physics and is a promising candidate for a unified physical theory. This book offers a comprehensive overview of the theory, structured in four parts: The first lays the necessary mathematical and physical foundations; the second offers an introduction to the theory and the causal action principle; the third describes the mathematical tools for analyzing causal fermion systems; and the fourth gives an outlook on the key physical applications.

With relevance across mathematical and theoretical physics, the book is aimed at graduate students and researchers interested in novel approaches to the structure of spacetime and alternative perspectives to the more established quantum field theories. It can be used for advanced courses in the subject or as a reference for research and self-guided study. Exercises are included at the end of each chapter to build and develop key concepts.

FELIX FINSTER is a full professor of mathematics at the University of Regensburg, Germany. Following postdoctoral research at Harvard University, he was a member of the Max Planck Institute for Mathematics in the Sciences in Leipzig for four years. He has been a professor of mathematics at the University of Regensburg since 2002 and works on general relativity and quantum field theory.

SEBASTIAN KINDERMANN is currently a teacher at the Comenius Gymnasium in Deggendorf, Germany. He studied physics and mathematics at the University of Regensburg, completing his master's degree in 2020.

JAN-HENDRIK TREUDE wrote his PhD thesis at the University of Regensburg, graduating in 2015. Currently, he is Fachbereichsreferent (manager of department) of the Department of Mathematics and Statistics at the University of Konstanz, Germany.

CAMBRIDGE MONOGRAPHS ON MATHEMATICAL PHYSICS

- S. J. Aarseth *Gravitational N-Body Simulations: Tools and Algorithms*[†]
D. Ahluwalia *Mass Dimension One Fermions*
J. Ambjørn, B. Durhuus and T. Jonsson *Quantum Geometry: A Statistical Field Theory Approach*[†]
A. M. Anile *Relativistic Fluids and Magneto-fluids: With Applications in Astrophysics and Plasma Physics*
J. A. de Azcárraga and J. M. Izquierdo *Lie Groups, Lie Algebras, Cohomology and Some Applications in Physics*[†]
O. Babelon, D. Bernard and M. Talon *Introduction to Classical Integrable Systems*[†]
F. Bajardi and S. Capozziello *Noether Symmetries in Theories of Gravity*
F. Bastianelli and P. van Nieuwenhuizen *Path Integrals and Anomalies in Curved Space*[†]
D. Baumann and L. McAllister *Inflation and String Theory*[†]
V. Belinski and M. Henneaux *The Cosmological Singularity*[†]
V. Belinski and E. Verdaguer *Gravitational Solitons*[†]
J. Bernstein *Kinetic Theory in the Expanding Universe*[†]
G. F. Bertsch and R. A. Broglia *Oscillations in Finite Quantum Systems*[†]
N. D. Birrell and P. C. W. Davies *Quantum Fields in Curved Space*[†]
K. Bolejko, A. Krasinski, C. Hellaby and M-N. Célérier *Structures in the Universe by Exact Methods: Formation, Evolution, Interactions*
D. M. Brink *Semi-Classical Methods for Nucleus-Nucleus Scattering*[†]
M. Burgess *Classical Covariant Fields*[†]
E. A. Calzetta and B.-L. B. Hu *Nonequilibrium Quantum Field Theory*
S. Carlip *Quantum Gravity in 2+1 Dimensions*[†]
P. Cartier and C. DeWitt-Morette *Functional Integration: Action and Symmetries*[†]
J. C. Collins *Renormalization: An Introduction to Renormalization, the Renormalization Group and the Operator-Product Expansion*[†]
P. D. B. Collins *An Introduction to Regge Theory and High Energy Physics*[†]
M. Creutz *Quarks, Gluons and Lattices*[†]
P. D. D'Eath *Supersymmetric Quantum Cosmology*[†]
J. Dereziński and C. Gérard *Mathematics of Quantization and Quantum Fields*
F. de Felice and D. Bini *Classical Measurements in Curved Space-Times*
F. de Felice and C. J. S. Clarke *Relativity on Curved Manifolds*[†]
B. DeWitt *Supermanifolds, 2nd edition*[†]
P. G. O. Freund *Introduction to Supersymmetry*[†]
F. G. Friedlander *The Wave Equation on a Curved Space-Time*[†]
J. L. Friedman and N. Stergioulas *Rotating Relativistic Stars*
Y. Frishman and J. Sonnenschein *Non-Perturbative Field Theory: From Two Dimensional Conformal Field Theory to QCD in Four Dimensions*
J. A. Fuchs *Affine Lie Algebras and Quantum Groups: An Introduction, with Applications in Conformal Field Theory*[†]
J. Fuchs and C. Schweigert *Symmetries, Lie Algebras and Representations: A Graduate Course for Physicists*[†]
Y. Fujii and K. Maeda *The Scalar-Tensor Theory of Gravitation*[†]
J. A. H. Futterman, F. A. Handler and R. A. Matzner *Scattering from Black Holes*[†]
A. S. Galperin, E. A. Ivanov, V. I. Ogievetsky and E. S. Sokatchev *Harmonic Superspace*[†]
R. Gambini and J. Pullin *Loops, Knots, Gauge Theories and Quantum Gravity*[†]
T. Gannon *Moonshine beyond the Monster: The Bridge Connecting Algebra, Modular Forms and Physics*[†]
A. García-Díaz *Exact Solutions in Three-Dimensional Gravity*
M. Göckeler and T. Schücker *Differential Geometry, Gauge Theories, and Gravity*[†]
C. Gómez, M. Ruiz-Altaba and G. Sierra *Quantum Groups in Two-Dimensional Physics*[†]
M. B. Green, J. H. Schwarz and E. Witten *Superstring Theory Volume 1: Introduction*
M. B. Green, J. H. Schwarz and E. Witten *Superstring Theory Volume 2: Loop Amplitudes, Anomalies and Phenomenology*
V. N. Gribov *The Theory of Complex Angular Momenta: Gribov Lectures on Theoretical Physics*[†]
J. B. Griffiths and J. Podolský *Exact Space-Times in Einstein's General Relativity*[†]
T. Harko and F. Lobo *Extensions of f(R) Gravity: Curvature-Matter Couplings and Hybrid Metric-Palatini Gravity*
S. W. Hawking and G. F. R. Ellis *The Large Scale Structure of Space-Time*[†]
J. Harnad and F. Balogh *Tau Functions and their Applications*
B. B. Hu and E. Verdaguer *Semiclassical and Stochastic Gravity*
F. Iachello and A. Arima *The Interacting Boson Model*[†]

- F. Iachello and P. van Isacker *The Interacting Boson-Fermion Model*[†]
- C. Itzykson and J. M. Drouffe *Statistical Field Theory Volume 1: From Brownian Motion to Renormalization and Lattice Gauge Theory*[†]
- C. Itzykson and J. M. Drouffe *Statistical Field Theory Volume 2: Strong Coupling, Monte Carlo Methods, Conformal Field Theory and Random Systems*[†]
- G. Jaroszkiewicz *Principles of Discrete Time Mechanics*
- G. Jaroszkiewicz *Quantized Detector Networks*
- C. V. Johnson *D-Branes*[†]
- P. S. Joshi *Gravitational Collapse and Spacetime Singularities*[†]
- J. I. Kapusta and C. Gale *Finite-Temperature Field Theory: Principles and Applications, 2nd edition*[†]
- V. E. Korepin, N. M. Bogoliubov and A. G. Izergin *Quantum Inverse Scattering Method and Correlation Functions*[†]
- K. Krasnov *Formulations of General Relativity*
- J. Kroon *Conformal Methods in General Relativity*
- M. Le Bellac *Thermal Field Theory*[†]
- L. Lusanna *Non-Inertial Frames and Dirac Observables in Relativity*
- Y. Makeenko *Methods of Contemporary Gauge Theory*[†]
- S. Mallik and S. Sarkar *Hadrons at Finite Temperature*
- A. Malyarenko and M. Ostojia-Starzewski *Tensor-Valued Random Fields for Continuum Physics*
- N. Manton and P. Sutcliffe *Topological Solitons*[†]
- N. H. March *Liquid Metals: Concepts and Theory*[†]
- I. Montvay and G. Münster *Quantum Fields on a Lattice*[†]
- P. Nath *Supersymmetry, Supergravity, and Unification*
- L. O'Raifeartaigh *Group Structure of Gauge Theories*[†]
- T. Ortín *Gravity and Strings, 2nd edition*
- A. M. Ozorio de Almeida *Hamiltonian Systems: Chaos and Quantization*[†]
- M. Paranjape *The Theory and Applications of Instanton Calculations*
- L. Parker and D. Toms *Quantum Field Theory in Curved Spacetime: Quantized Fields and Gravity*
- R. Penrose and W. Rindler *Spinors and Space-Time Volume 1: Two-Spinor Calculus and Relativistic Fields*[†]
- R. Penrose and W. Rindler *Spinors and Space-Time Volume 2: Spinor and Twistor Methods in Space-Time Geometry*[†]
- S. Pokorski *Gauge Field Theories, 2nd edition*[†]
- J. Polchinski *String Theory Volume 1: An Introduction to the Bosonic String*[†]
- J. Polchinski *String Theory Volume 2: Superstring Theory and Beyond*[†]
- J. C. Polkinghorne *Models of High Energy Processes*[†]
- V. N. Popov *Functional Integrals and Collective Excitations*[†]
- L. V. Prokhorov and S. V. Shabanov *Hamiltonian Mechanics of Gauge Systems*
- S. Raychaudhuri and K. Sridhar *Particle Physics of Brane Worlds and Extra Dimensions*
- A. Recknagel and V. Schiomerus *Boundary Conformal Field Theory and the Worldsheet Approach to D-Branes*
- M. Reuter and F. Saueressig *Quantum Gravity and the Functional Renormalization Group*
- R. J. Rivers *Path Integral Methods in Quantum Field Theory*[†]
- R. G. Roberts *The Structure of the Proton: Deep Inelastic Scattering*[†]
- P. Romatschke and U. Romatschke *Relativistic Fluid Dynamics In and Out of Equilibrium: And Applications to Relativistic Nuclear Collisions*
- C. Rovelli *Quantum Gravity*[†]
- W. C. Saslaw *Gravitational Physics of Stellar and Galactic Systems*[†]
- R. N. Sen *Causality, Measurement Theory and the Differentiable Structure of Space-Time*
- M. Shifman and A. Yung *Supersymmetric Solitons*
- Y. M. Shnir *Topological and Non-Topological Solitons in Scalar Field Theories*
- H. Stephani, D. Kramer, M. MacCallum, C. Hoenselaers and E. Herlt *Exact Solutions of Einstein's Field Equations, 2nd edition*[†]
- J. Stewart *Advanced General Relativity*[†]
- J. C. Taylor *Gauge Theories of Weak Interactions*[†]
- T. Thiemann *Modern Canonical Quantum General Relativity*[†]
- D. J. Toms *The Schwinger Action Principle and Effective Action*[†]
- A. Vilenkin and E. P. S. Shellard *Cosmic Strings and Other Topological Defects*[†]
- R. S. Ward and R. O. Wells, Jr *Twistor Geometry and Field Theory*[†]
- E. J. Weinberg *Classical Solutions in Quantum Field Theory: Solitons and Instantons in High Energy Physics*[†]
- J. R. Wilson and G. J. Mathews *Relativistic Numerical Hydrodynamics*[†]

[†] Available in paperback

Causal Fermion Systems

An Introduction to Fundamental Structures, Methods and
Applications

FELIX FINSTER

University of Regensburg

SEBASTIAN KINDERMANN

Comenius Gymnasium Deggendorf

JAN-HENDRIK TREUDE

University of Konstanz



CAMBRIDGE
UNIVERSITY PRESS



Shaftesbury Road, Cambridge CB2 8EA, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre,
New Delhi – 110025, India

103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of Cambridge University Press & Assessment,
a department of the University of Cambridge.

We share the University's mission to contribute to society through the pursuit of
education, learning and research at the highest international levels of excellence.

www.cambridge.org

Information on this title: www.cambridge.org/9781009632621

DOI: [10.1017/9781009632638](https://doi.org/10.1017/9781009632638)

© Felix Finster, Sebastian Kindermann and Jan-Hendrik Treude 2026

This publication is in copyright. Subject to statutory exception and to the provisions of
relevant collective licensing agreements, with the exception of the Creative Commons
version the link for which is provided below, no reproduction of any part may take place
without the written permission of Cambridge University Press & Assessment.

An online version of this work is published at doi.org/10.1017/9781009632638 under a
Creative Commons Open Access license CC-BY-NC 4.0 which permits re-use, distribution
and reproduction in any medium for non-commercial purposes providing appropriate credit
to the original work is given and any changes made are indicated. To view a copy of this
license visit <https://creativecommons.org/licenses/by-nc/4.0>

When citing this work, please include a reference to the
DOI [10.1017/9781009632638](https://doi.org/10.1017/9781009632638)

First published 2026

A catalogue record for this publication is available from the British Library

*A Cataloging-in-Publication data record for this book is available from the Library
of Congress*

ISBN 978-1-009-63262-1 Hardback

Cambridge University Press & Assessment has no responsibility for the persistence
or accuracy of URLs for external or third-party internet websites referred to in this
publication and does not guarantee that any content on such websites is, or will
remain, accurate or appropriate.

For EU product safety concerns, contact us at Calle de José Abascal, 56, 1º, 28003 Madrid,
Spain, or email eugpsr@cambridge.org