Lecture Notes in Physics 855

Ten Physical Applications of Spectral Zeta Functions

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1. Auflage 2012. Taschenbuch. xiv, 227 S. Paperback
ISBN 978 3 642 29404 4
Format (B x L): 15,5 x 23,5 cm
Gewicht: 379 g

Preface

The years elapsed since the First Edition was issued have witnessed an impressive evolution of some of the applications here considered, maybe not so of the mathematical background which constitutes the first part, which evolves at a much more steady pace. In writing this Second Edition the same guiding idea has been strictly respected to include as many applications as possible, at the price of explaining things in the most concise way still compatible with the comprehensibility of the different subjects treated.

The new text includes some additions to Chap. 1, specifically two sections on the general definition of the zeta function of a pseudo-differential operator and on operator regularization. In Chap. 4 a new Section has been included on extended Chowla–Selberg series formulas, associated with arbitrary forms of the type of a quadratic plus a linear plus a constant term. The second Section in Chap. 5, on the experimental verification of the Casimir effect, has been suppressed, for the account there had been rendered clearly obsolete by the many and very important advances in this field during the last fifteen years. A very brief, one-paragraph description of the last has been included at the end of the first Section. It is basically a guide to a number of relevant references where the reader will find the new developments in this presently very hot and rapidly growing field. In Chap. 6 a new application has been added, Sect. 6.5, on the treatment of scalar and vector fields on a spacetime with a noncommutative toroidal part. The title of the Chapter has been changed accordingly.

In Chap. 7 there is now a new Section on the combination of zeta and Hadamard regularizations, in relation with computations of the Casimir effect under realistic physical conditions. In Chap. 9 only the title has changed, to be consistent with the fact that an additional application was added to Chap. 6. Finally, Chap. 10 is new, and contains an application of the zeta function techniques to the regularization of the expected imprint of quantum vacuum fluctuations in cosmology, in particular, in relation with the cosmological constant problem. In all, the number of applications in this Second Edition has now raised to twelve, what could justify a change of the title of the book itself. However, being it just a second edition this would not be advisable, and has not been done.

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Preface to the First Edition

This monography is, in the first place, a commented guide that invites the reader to plunge into the thrilling world of zeta functions and their applications in physics. Different aspects of this field of knowledge are considered, as one can see specifically in the table of contents.

The level of the book is elementary. It is intended for people with no or little knowledge of the subject. Everything is explained in full detail, in particular, the mathematical difficulties and tricky points, which too often constitute an insurmountable barrier for those who would have liked to become acquainted with that matter but never dared to ask (or did not manage to understand more complete, higher-level treatises). In this sense the present work is to be considered as a basic introduction to other books that have appeared recently.

Concerning the physical applications of the method of zeta-function regularization here described, quite a big choice is presented. The reader must be warned, however, that I have not tried to explain the underlying physical theories in complete detail (since this is undoubtedly out of scope), but rather to illustrate—simply and clearly—the precise way how the method must be applied. Sometimes zeta regularization is explicitly compared in the text with other procedures the reader is supposed to be more familiar with (as cut-off or dimensional regularization). Again, a very detailed comparison would have taken us too far away from the general purpose and, knowing the other procedures, the reader is already entitled to confront them directly. In the examples only physical systems with a known spectrum have been considered. This is the most simple case—although the procedure itself can be (and has been) extended to much more general situations.

I would like to thank my colleagues and friends Alfred Actor, Michael Bordag, Iver Brevik, Andrei Bytsenko, Guido Cognola, Klaus Kirsten, Yuri Kubyshin, Sergi Leseduarte, Sergei Odintsov, Sergi Rafels-Hildebrandt, August Romeo, Luciano Vanzo, and Sergio Zerbini. My gratitude goes to all of them for really enjoyable discussions and, in some cases, for specific contributions to the original papers on which part of this report is based.

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