RELATIVISTIC QUANTUM PHYSICS

From Advanced Quantum Mechanics to Introductory Quantum Field Theory

Quantum physics and special relativity theory were two of the greatest breakthroughs in physics during the twentieth century and contributed to paradigm shifts in physics. This book combines these two discoveries to provide a complete description of the fundamentals of relativistic quantum physics, guiding the reader effortlessly from relativistic quantum mechanics to basic quantum field theory.

The book gives a thorough and detailed treatment of the subject, beginning with the classification of particles, the Klein–Gordon equation and the Dirac equation. It then moves on to the canonical quantization procedure of the Klein–Gordon, Dirac, and electromagnetic fields. Classical Yang–Mills theory, the LSZ formalism, perturbation theory and elementary processes in QED are introduced, and regularization, renormalization, and radiative corrections are explored. With exercises scattered through the text and problems at the end of most chapters, the book is ideal for advanced undergraduate and graduate students in theoretical physics.

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CAMBRIDGE
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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

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a department of the University of Cambridge.

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www.cambridge.org
Information on this title: www.cambridge.org/9780521767262

First published 2011

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

Library of Congress Cataloging-in-Publication data
Ohlsson, Tommy, 1973–
Relativistic quantum physics : from advanced quantum mechanics to introductory
quantum field theory / Tommy Ohlsson.
p. cm.
ISBN 978-0-521-76726-2 (Hardback)
1. Quantum theory. I. Title.
QC174.12.O35 2011
530.12–dc23

2011018860

ISBN 978-0-521-76726-2 Hardback

In memory of my father Dick

Contents

Preface

This book is based on my lectures in the course 'Relativistic Quantum Physics' at the Royal Institute of Technology (KTH) in Stockholm, Sweden. These lectures have been given four times during the academic years 2006–2007, 2007–2008, 2008–2009, and 2009–2010. The main sources of inspiration for the lectures were the books A. Z. Capri, *Relativistic Quantum Mechanics and Introduction to Quantum Field Theory*, World Scientific (2002) and M. E. Peskin and D. V. Schroeder, *An Introduction to Quantum Field Theory*, Addison-Wesley (1995), and indeed, this book serves as a textbook for relativistic quantum mechanics with continuation to basic quantum field theory. The book is mainly intended for final-year undergraduate students in physics or first-year graduate students in physics and/or theoretical physics, who want to learn relativistic quantum mechanics, the basics of quantum field theory, and the techniques of calculating cross-sections for elementary reactions in quantum electrodynamics. Thus, the book should be suitable for any course on relativistic quantum mechanics as well as it might be suitable for a beginners' course on quantum field theory. In summary, the book is a self-contained technical treatment on relativistic quantum mechanics, introductory quantum field theory, and the step in between, i.e. it should fill the gap between advanced quantum mechanics and quantum field theory, which I have called *relativistic quantum physics*. It contains a thorough and detailed mathematical treatment of the subject with smaller exercises throughout the whole text and larger problems at the end of most chapters.

I am deeply grateful to Johannes Bergström, Jonas de Woul, and Dr Jens Wirstam for careful proof-reading of earlier versions of the manuscript of this book and for useful comments, discussions, and suggestions how to improve the book. I am indebted to my former Ph.D. supervisor Professor emeritus Håkan Snellman for teaching me that physics is a descriptive science, which indeed does not explain anything. I would also like to thank my two friends Björn Sjödin and Jens Wirstam, who left science for 'industry', but never lost interest in it, and with whom I

obtained many inspiring ideas how to develop this book further. Discussions with Dr Mattias Blennow, Dr Tomas Hällgren, Henrik Melbéus, and Dr He Zhang have been helpful in the process of development. In addition, I would like to thank Professor Mats Wallin, who suggested to me to include the topic 'graphene' in this book.

The author gratefully acknowledges financial support from the degree program 'Engineering Physics' (especially, Professor Leif Kari) at KTH for the development of this book.

Finally, last but not least, I would like to thank my family and friends for always being there for me. This applies particularly to my wife Linda, but also to my mother Inga-Lill and my sister Therése.