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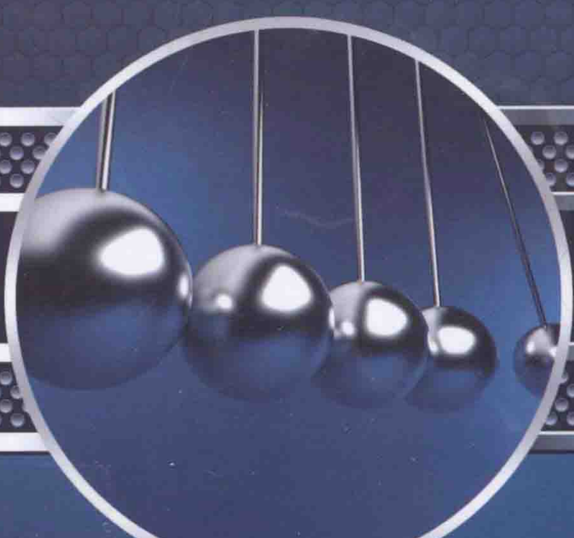
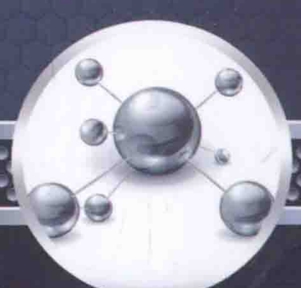
相对论量子力学与量子场论

Relativistic Quantum Mechanics and Quantum Field Theory

(印) V.德文纳森(V.Devanathan) 著





机械工业出版社
CHINA MACHINE PRESS

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Relativistic Quantum Mechanics and Quantum Field Theory

（影印版）

（印）V. 德文纳森（V. Devanathan） 著

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本书研究了单粒子相对论波动方程和量子场论的基本元素，全书共有11章和两个附录。在简要介绍克莱因-戈尔登（Klein-Gordon）方程之后，详细讨论了狄拉克（Dirac）方程，包括该方程的自由粒子解，讨论了费曼（Feynman）的正电子理论，介绍了如何利用费曼图来简化量子电动力学中辐射与物质相互作用的计算。用威克（Wick）定理从S矩阵导出费曼图表明，费曼的方法与另一种更为普遍的量子场论方法是等价的。本书还介绍了有关量子电动力学、标量场、狄拉克场、电磁场、场相互作用等内容。书的最后简短讨论了量子场论怎样超越量子电动力学，从而涵盖弱相互作用和强相互作用，以及怎样导出基本粒子标准模型的理论形式。

本书每章都配有复习题、问题和题解，帮助学生理解本章的主要内容，检查学生对所学内容的掌握情况。题解对每个问题都给出详细的解答，方便学生自学和复习，这是其他教材所不具备的。

本书可作为高等学校物理专业学生的基础教材，也可供有关专业教师、科研人员和工程技术人员的参考。

Originally published in English as
RELATIVISTIC QUANTUM MECHANICS AND QUANTUM FIELD THEORY
Authored by:
V. Devanathan
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图书在版编目（CIP）数据

相对论量子力学与量子场论＝Relativistic Quantum Mechanics and Quantum Field Theory：英文/（印）德文纳森（Devanathan，V.）著．—北京：机械工业出版社，2014.6
（时代教育：国外高校优秀教材精选）
ISBN 978-7-111-46580-5

Ⅰ.①相… Ⅱ.①德… Ⅲ.①相对论—量子力学—高等学校—教材—英文②量子场论—高等学校—教材—英文 Ⅳ.①O413

中国版本图书馆CIP数据核字（2014）第087598号

机械工业出版社（北京市百万庄大街22号　邮政编码100037）
策划编辑：李永联　责任编辑：李永联
版式设计：常天培　责任校对：刘怡丹
封面设计：马精明　责任印制：李　洋
北京市四季青双青印刷厂印刷
2014年6月第1版第1次印刷
169mm×239mm・17.25印张・319千字
标准书号：ISBN 978-7-111-46580-5
定价：35.00元

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前　　言

自从我写了一本关于量子力学的书后，我就希望继续写一本关于相对论量子力学和量子场论的书作为它的续集。这是由于多数大学的物理专业都开设一门两个学期的课程，包括一学期的量子力学，一学期的相对论量子力学和量子场论。

但与此同时，勒赫里（Lahri）和姆帕勒（Pal）著的《量子场论入门》以及巴萨拉席（R. Parthasarathy）著的《相对论量子力学》的问世使得我更加犹豫是否要继续完成这本书，因而也推迟了这本书手稿的完成。或许有人会问，在这一方面已经有了这么多优秀书籍的情况下，还有什么必要使得我再写一本?

在金奈（Chennai），12 月～1 月是举办音乐节的时候。有很多的音乐厅，人们会聚集在一起听他们喜欢的音乐。大多数音乐家唱几乎相同的歌曲，但风格不同。热衷音乐的人们不但喜欢音乐里的不同特色和风格上的微小变化，还欢迎多种类型音乐的同时演出和评论家们对多样音乐统一性的辩论。

因此，每个作者都有他自己表现主题的风格和方式。同样，我也有自己独特的表现风格和方法。一个挑剔的学生会发现一些题目在一本书中比在其他书中更容易理解。若他希望对学科有整体的了解，那他更愿意参考更多的书。

本着这种精神，我鼓起勇气冒险出版这本书。我被费曼处理量子电动力学的直观方法深深吸引，这一方法给了我们研究物理过程的直观图像和计算矩阵元的经验法则。施温格（Schwinger）曾经评价，费曼确实使量子电动力学得以“普及”。比费曼更进一步，赛森（Dyson）使得费曼图得以流行，而且也证明了费曼的方法与朝永振一郎（Tomonago）和施温格的更普遍的场论方法是等价的。你会在本书中发现费曼贡献的精彩之处，以及这种贡献是怎样使人得到的结果与采用量子场论得到的结果相同。

本书第 1～5 章涉及单粒子的相对论波方程和费曼的量子电动力学方法。第 6～10 章涉及量子场论的基本元素，以及如何将它应用于量子电动力学的研究。结果表明，量子场论更具有一般性，不仅适用于电磁相互作用，而且已被推广至弱相互作用和强相互作用。因此，量子场论已经统一了四种基本相互作用中的三种：电磁相互作用、弱相互作用和强相互作用，只有引力相互作用除外。

量子场论被认为应当是一个更为基本的理论的低能极限（小于1000GeV）。弦理论和具有超对称的弦理论，即超弦理论，似乎是潜在的适用于所有四种基本相互作用的更基本的理论。本书最后一章关于量子场论的最新发展中将介绍这一方面的现状。

作者没有列出所有的参考资料。一些原创性论文的引用以脚注的形式在文中说明，一些引用的书以及综述性文章则包含在本书最后的参考文献中。

本书的一个显著特点是在每一章的最后都有复习题、问题和解，这将使学生加深对课程内容的理解。作者欢迎对本书提出的任何改进建议，可以通过电子邮件联系：vdevanathan@hotmail.com。

不能期望读者从第一页开始就按顺序读到最后一页。记号和符号通常在本书中首次引入时定义。读者面临的困难通常是阅读时辨认这些记号和符号。“附录 A　记号和符号表”，可帮助这样的读者。

在过去的几年中，在马德拉斯（Madras）大学、泰米尔纳德邦（Tamil Nadu）科学院和科学城的共同主持下，我给物理系的研究生举办了暑期培训课（STPIP），这使我能与现在和过去的师生互动，并产生了写这本书的兴趣。感谢 M. Anandakrishnan 博士、P. Iyamperumal 博士、J. Devasenapathy 博士、V. Ravichandran 博士、A. Stephen 博士和核物理教研室所有成员在组织这些夏季项目中给予的充分合作。

非常感谢 K. Sivaji 博士提供所有的关于课程的相关文献。感谢 S. Gopinath 博士提供软件支持。特别感谢 N. K. Mehre 先生和 Narosa 出版社的常务董事欣然同意承接本书的出版，并容许延迟提交照相制版的手稿。

最后，我要感谢我的家人对我完成这个项目的宽容和支持。

作　者

注：本前言由北京工商大学陈晓白教授翻译。

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Preface

Ever since I wrote my book on Quantum Mechanics, I wished to follow it up with another book on Relativistic Quantum Mechanics and Quantum Field Theory as a sequel, since most of the Universities have a two-semester course in M.Sc. (Physics), one on Quantum Mechanics and the other on Relativistic Quantum Mechanics and Quantum Field Theory.

In the meantime, the book on "Relativistic Quantum Mechanics" by R. Parthasarathy has come out in addition to the already published work "The First Book on Quantum Field Theory" by Lahri and Pal from the present publisher. This has made me more hesitant to go ahead with the project and hence the delay in completing the manuscript of the book. Hence one may rightly ask, what is the need for another book when there are so many excellent books on the subject?

In Chennai, December-January is the season for music festivals. There are very many music concert halls, to which the people flock together to listen to the musicians of their choice. Most of the musicians sing almost the same songs but with different flavours. The discerning public not only enjoy the different flavours and the small variations in style but welcome the variety in unison and the music connoisseurs wax eloquent on the unity in diversity.

Thus each author has his own style of presentation and a distinct approach to the subject. In the same way, I have developed my own style of presentation and a distinctive approach to the subject. A discerning student will find some topics in one book more intelligible than in other books and he would wish to refer to more books to have a holistic view of the subject.

In that spirit, I have gathered courage to venture on the publication of this book. I have been greatly fascinated by Feynman's intuitive approach to Quantum Electrodynamics which has given a visual picture of the processes that we study and a thumb rule for calculating the matrix elements. As Schwinger once remarked, Feynman has indeed carried the

Quantum Electrodynamics to the "masses". More than Feynman, it was Dyson who had popularized Feynman diagrams and demonstrated that Feynman's intuitive approach is equivalent to the more general field theoretic approach of Tomonago and Schwinger. You will find in this book the highlights of Feynman's contribution and how it leads to the same results that one can arrive by the Quantum Field Theory.

Chapters 1 to 5 deal with single particle relativistic wave equations and Feynman's approach to Quantum Electrodynamics. Chapters 6 to 10 deal with the elements of Quantum Field Theory and how one can apply it to the study of Quantum Electrodynamics. It is shown that Quantum Field Theory is more general and applicable not only to electromagnetic interaction but has the potential of being extended to weak interaction and strong interaction. Thus the Quantum Field Theory has unified the three of the four known fundamental interactions, electromagnetic, weak and strong interactions. Only the gravitational interaction lies outside its purview.

It is being felt that the Quantum Field Theory should be the low-energy limit (less than 1000 GeV) of a more fundamental theory. String Theory and String Theory with super-symmetry known as Superstring theory seem to be the potential candidates for such a more fundamental theory which is applicable to all the four fundamental interactions. The last chapter on Recent Developments deals with the emerging scenario on this subject.

The author has not made any serious effort to include all the references. Some original papers have been cited in the text as footnote and some books and review articles are included in the Bibliography at the end.

A notable feature of this book is the inclusion of review questions, problems and solutions to problems at the end of each chapter which will definitely promote a clearer and deeper understanding and appreciation of the subject. The author welcomes any suggestion for improvement and he can be contacted by email: vdevanathan@hotmail.com.

One cannot expect the reader to start from the first page and go to the last page in a sequential order. Notations and symbols are defined usually in the text when they are first introduced. The difficulty that a reader usually faces is in deciphering notations and symbols when he wants to refer to any specific topic. To help such a reader, I have appended Appendix A: List of Symbols and Notations.

For the past several years, I had the privilege of organizing the Summer

Training Programmes in Physics (STPIP) for the post-graduate students in Physics, under the joint auspices of the University of Madras, Tamil Nadu Academy of Sciences and the Science City. This has enabled me to interact with the present and past students and the faculties and sustain my interest in bringing out this book. Thanks are due to Dr. M. Anandakrishnan, Dr. P. Iyamperumal, Dr. J. Devasenapathy, Dr. V. Ravichandran, Dr. A. Stephen and all the members of the Department of Nuclear Physics for extending their fullest cooperation to me in organizing these summer programs.

I am grateful to Dr. K. Sivaji for making available all the relevant literature on the subject and to Mr. S. Gopinath for offering the software support. Special thanks are due to Mr. N. K. Mehra, Managing Director of Narosa Publishing House for readily agreeing to undertake the publication of this book and tolerating the inordinate delay in my submission of the camera-ready manuscript.

In conclusion, I wish to thank the members of my family for their tolerance and support that they have extended to me in completing this project.

V. Devanathan
March 2011

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