

## <<粒子物理学中的超对称>>

### 图书基本信息

书名：<<粒子物理学中的超对称>>

13位ISBN编号：9787510005626

10位ISBN编号：7510005620

出版时间：2010年04月

出版时间：世界图书出版公司

作者：艾奇逊(Aitchison.I.)

页数：222

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## 前言

This book is intended to be an elementary and practical introduction to supersymmetry in particle physics. More precisely, I aim to provide an accessible, self-contained account of the basic theory required for a working understanding of the 'Minimal Supersymmetric Standard Model' (MSSM), including 'soft' symmetry breaking. Some simple phenomenological applications of the model are also developed in the later chapters. The study of supersymmetry (SUSY) began in the early 1970s, and there is now a very large, and still growing, research literature on the subject, as well as many books and review articles. However, in my experience the existing sources are generally suitable only for professional (or intending) theorists. Yet searches for SUSY have been pursued in experimental programmes for some time, and are prominent in experiments planned for the Large Hadron Collider at CERN. No direct evidence for SUSY has yet been found. Nevertheless, for the reasons outlined in Chapter 1, supersymmetry at the TeV scale has become the most highly developed framework for guiding and informing the exploration of physics beyond the Standard Model. This dominant role of supersymmetry, both conceptual and phenomenological, suggests a need for an entry-level introduction to supersymmetry, which is accessible to the wider community of particle physicists. The first difficulty presented by conventional texts on supersymmetry - and it deters many students - is one of notation. Right from the start, discussions tend to be couched in terms of a spinor notation that is generally not familiar from standard courses on the Dirac equation - namely, that of either 'dotted and undotted 2-component Weyl spinors', or '4-component Majorana spinors'. This creates something of a conceptual discontinuity between what most students already know, and what they are trying to learn; it becomes a pedagogical barrier. By contrast, my approach builds directly on knowledge of Dirac spinors in a conventional representation, using 2-component ('half-Dirac') spinors, without necessarily requiring the more sophisticated dotted and undotted formalism. The latter is, however, at roughly the half-way stage in the book, all the elements necessary for understanding the construction of the MSSM (or variants thereof) are now in place. The model is defined in Chapter 8, and immediately applied to exhibit gauge-coupling unification. Elementary ideas of SUSY breaking are introduced in Chapter 9, together with the phenomenologically important notion of 'soft' supersymmetry-breaking parameters. The remainder of the book is devoted to simple applications: Higgs physics (Chapter 10), sparticle masses (Chapter 11) and sparticle production processes (Chapter 12).

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### 内容概要

This book is intended to be an elementary and practical introduction to supersymmetry in particle physics. More precisely, I aim to provide an accessible, self-contained account of the basic theory required for a working understanding of the Minimal Supersymmetric Standard Model (MSSM), including soft symmetry breaking. Some simple phenomenological applications of the model are also developed in the later chapters.

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作者简介

作者：(英国)艾奇逊(Aitchison.I.)

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## 章节摘录

插图：Accepting that (1.34) captures the essence of the matter, we can now begin to see what a radical idea supersymmetry really is. Equation (1.34) says, roughly speaking, that if you do two SUSY transformations generated by the  $Q$  terms, one after the other, you get the energy-momentum operator. Or, to put it even more strikingly (but quite equivalently), you get the space-time translation operator, i.e. a derivative. Turning it around, the SUSY spinorial  $Q$ 's are like square roots of 4-momentum, or square roots of derivatives!

It is rather like going one better than the Dirac equation, which can be viewed as providing the square root of the Klein-Gordon equation: how would we take the square root of the Dirac equation?

It is worth pausing to take this in properly. Four-dimensional derivatives are firmly locked to our notions of a four-dimensional space-time. In now entertaining the possibility that we can take square roots of them, we are effectively extending our concept of space-time itself, just as, when the square root of  $-1$  is introduced, we enlarge the real axis to the complex (Argand) plane. That is to say, if we take seriously an algebra involving both  $P$  and the  $Q$ 's we shall have to say that the space-time co-ordinates are being extended to include further degrees of freedom, which are acted on by the  $Q$ 's, and that these degrees of freedom are connected to the standard ones by means of transformations generated by the  $Q$ 's. These further degrees of freedom are, in fact, fermionic. So we may say that SUSY invites us to contemplate 'fermionic dimensions', and enlarge space-time to 'superspace'. SUSY is often thought of in terms of (approximately) degenerate multiplets of bosons and fermions. Of course, that aspect is certainly true, phenomenologically important, and our main concern in this book; nevertheless, the fermionic enlargement of space-time is arguably a more striking concept, and we shall provide an introduction to it in Chapter 6. One final remark on motivations: if you believe in String Theory (and it still seems to be the most promising framework for a consistent quantum theory of gravity), then the phenomenologically most attractive versions incorporate supersymmetry, some trace of which might remain in the theories that effectively describe physics at presently accessible energies.

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