Solid State Physics

SOLID STATE PHYSICS

Second Edition

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Editors' preface to the Manchester Physics Series

The first book in the Manchester Physics Series was published in 1970, and other titles have been added since, with total sales world-wide of more than a quarter of a million copies in English language editions and in translation. We have been extremely encouraged by the response of readers, both colleagues and students. The books have been reprinted many times, and some of our titles have been rewritten as new editions in order to take into account feedback received from readers and to reflect the changing style and needs of undergraduate courses.

The Manchester Physics Series is a series of textbooks at undergraduate level. It grew out of our experience at Manchester University Physics Department, widely shared elsewhere, that many textbooks contain much more material than can be accommodated in a typical undergraduate course and that this material is only rarely so arranged as to allow the definition of a shorter self-contained course. In planning these books, we have had two objects. One was to produce short books: so that lecturers should find them attractive for undergraduate courses; so that students should not be frightened off by their encyclopaedic size or their price. To achieve this, we have been very selective in the choice of topics, with the emphasis on the basic physics together with some instructive, stimulating and useful applications. Our second aim was to produce books which allow courses of different length and difficulty to be selected, with emphasis on different applications. To achieve such flexibility we have encouraged authors to use flow diagams showing the logical connections between different chapters and to put some topics in starred sections. These cover more advanced and alternative material which is not required for the understanding of later parts of each volume. Although these books were conceived as a series, each of them is self-contained and can be used independently of the others. Several of them are suitable for wider use in other sciences. Each author's preface gives details about the level, prerequisites, etc., of his volume.

We are extremely grateful to the many students and colleagues, at Manchester and elsewhere, whose helpful criticisms and stimulating comments have led to many improvements. Our particular thanks go to the authors for all the work they have done, for the many new ideas they have contributed, and for discussing patiently, and often accepting, our many suggestions and requests. We would also like to thank the publishers, John Wiley & Sons, who have been most helpful.

F. MANDL
R. J. ELLISON
D. J. SANDIFORD

January, 1987

The story of the creation was told in 200 words. Look it up if you don't believe me.—*Edgar Wallace*

Foreword

When the time came to consider a second edition of *Solid State Physics* I felt that I had already said what I had to say on the subject in the first edition. I also felt that the book was rather too idiosyncratic for many students. For these reasons I thought it would be better if the revision and updating were undertaken by another hand, and the editors shared this view.

We therefore approached Dr John Hook, a friend and colleague for many years, and I think the result justifies the decision. The new edition is, in my opinion, a substantial improvement on the old one, but it would not have occurred to me to write it like that.

September 1990 HENRY HALL

Author's preface to second edition

I accepted the invitation of the editors of the Manchester Physics Series to write a second edition of *Solid State Physics* for two main reasons. Firstly I felt that, although the approach adopted in the first edition had much to commend it, some re-ordering and simplification of the material was required to make the book more accessible to undergraduate students. Secondly there was a need to take account of some of the important developments that have occurred in solid state physics since 1973.

To achieve re-ordering and simplification it has been necessary to rewrite most of the first edition. A major change has been to introduce the idea of mobile electron states in solids through the free electron theory of metals rather than through the formation of energy bands by overlap of atomic states on neighbouring atoms. The latter approach was used in the first edition because it could be applied first to the dilute electron gas in semiconductors where an independent particle model might be expected to work. Although this was appealing to the experienced physicist, it proved difficult to the undergraduate student, who was forced to assimilate too many new ideas at the beginning. One feature of the first edition that I have retained is to delay for as long as possible a *formal* discussion of the reciprocal lattice and Brillouin zones in a three-dimensional crystal. Although these concepts provide an elegant general framework for describing many of the properties of crystalline solids, they are, like Maxwell's equations in electromagnetism, more likely to be appreciated by students if they have met some of the ideas earlier in a simpler context. The use of the formal framework is avoided in the early chapters by using one- and two-dimensional geometries whenever necessary.

To take account of recent developments the amount of material on semiconductor physics and devices has been substantially increased, a chapter has been added on the two-dimensional electron gas and quantum Hall effect, and sections on quasi-crystals, high-T_C superconductors and the use of electrons to probe surfaces have been included. A chapter on the electrical properties of insulators has also been added.

I have tried to conform to the aim of the Manchester Physics Series by producing a book of reasonable length (and thus cost), from which it is possible to define self-contained undergraduate courses of different length and difficulty. The problem with solid state physics in this context is that it contains many diverse topics so that many quite different courses are possible. I have had to be very selective therefore in my choice of subjects, which has been strongly influenced by the third year undergraduate solid state physics courses at Manchester. We currently have a basic course of 20 lectures, which is given at two levels; the courses cover material from Chapters 1–5 of this book and the higher level course also incorporates appropriate sections of Chapters 11–13. A further course of 20 lectures on selected topics in solid state physics currently covers magnetism, superconductivity and ferroelectricity (Chapters 7–10). The flow diagram inside the front cover can be used as an aid to the design of courses based on this book.

Important subjects that are not covered in this book are crystal defects and disordered solids. I would have liked to include a chapter on each of these topics but would have exceeded the length limit set by the publishers and editors had I done so.

Like the first edition, this book presupposes a background knowledge of properties of matter (interatomc potentials and their relation to binding energies and elastic moduli, kinetic theory), quantum mechanics (Schrödinger's equation and its solution to find energy eigenvalues and eigenfunctions), electricity and magnetism (Maxwell's equations and some familiarity with electric and magnetic fields in matter) and thermal physics (the Boltzmann factor and the Fermi and Bose distributions). Books in which this background information can be found are listed in the bibliography along with selected general reference books on solid state physics and some books and articles that provide further information on specific topics.

This book includes some more advanced and detailed material, which can be omitted without loss of continuity. Complete sections in this category are identified by starring and parts of sections are printed on a grey background.

The use of **bold** type for a technical term in the text, normally when the term is first encountered, indicates that a definition or explanation of the term can be found there. *Italic* type is used for emphasis.

I am very grateful to David Sandiford and Henry Hall for their helpful advice and constructive criticism. I would also like to thank Manchester undergraduate Colin Lally, who read the manuscript from the point of view of a prospective consumer; his reaction reassured me that the level was appropriate. Ian Callaghan's draughtmanship and photography was invaluable in producing many of the figures, and my son James helped willingly with some of the more mundane manuscript-preparation tasks.

September 1990 JOHN HOOK

TABLE OF CONSTANTS

Quantity	*Symbol*	*Value*	*Units*
Electron charge	e	1.602×10^{-19}	C
Electron mass	m	9.109×10^{-31}	kg
Proton mass	m_p	1.673×10^{-27}	kg
Neutron mass	m_n	1.675×10^{-27}	kg
Atomic mass unit	amu	1.661×10^{-27}	kg
Planck's constant	h	6.626×10^{-34}	J s
Planck's constant	$\hbar = h/2\pi$	1.055×10^{-34}	J s
Bohr radius	$a_0 = \hbar^2/me^2$	5.292×10^{-11}	m
Bohr magneton	$\mu_B = e\hbar/2m$	9.274×10^{-24}	$J\ T^{-1}$
Speed of light	c	2.998×10^{8}	$m\ s^{-1}$
Permeability of vacuum	μ_0	$4\pi \times 10^{-7}$	$H\ m^{-1}$
Permittivity of vacuum	$\varepsilon_0 = 1/\mu_0 c^2$	8.854×10^{-12}	$F\ m^{-1}$
Avogadro's number	N_A	6.022×10^{23}	mol^{-1}
Boltzmann's constant	k_B	1.381×10^{-23}	$J\ K^{-1}$
Gas constant	$R = N_A k_B$	8.315	$J\ K^{-1}\ mol^{-1}$

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★ Starred sections may be omitted as they are not required later in the book.