Introduction to Solid State Physics

EIGHTH EDITION

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Chapter 18, Nanostructures, was written by Professor Paul McEuen of Cornell University.

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About the Author

Charles Kittel did his undergraduate work in physics at M.I.T and at the Cavendish Laboratory of Cambridge University. He received his Ph.D. from the University of Wisconsin. He worked in the solid state group at Bell Laboratories, along with Bardeen and Shockley, leaving to start the theoretical solid state physics group at Berkeley in 1951. His research has been largely in magnetism and in semiconductors. In magnetism he developed the theories of ferromagnetic and antiferromagnetic resonance and the theory of single ferromagnetic domains, and extended the Bloch theory of magnons. In semiconductor physics he participated in the first cyclotron and plasma resonance experiments and extended the results to the theory of impurity states and to electron-hole drops.

He has been awarded three Guggenheim fellowships, the Oliver Buckley Prize for Solid State Physics, and, for contributions to teaching, the Oersted Medal of the American Association of Physics Teachers. He is a member of the National Academy of Science and of the American Academy of Arts and Sciences.

Preface

This book is the eighth edition of an elementary text on solid state/condensed matter physics for seniors and beginning graduate students of the physical sciences, chemistry, and engineering. In the years since the first edition was published the field has developed vigorously, and there are notable applications. The challenge to the author has been to treat significant new areas while maintaining the introductory level of the text. It would be a pity to present such a physical, tactile field as an exercise in formalism.

At the first edition in 1953 superconductivity was not understood; Fermi surfaces in metals were beginning to be explored and cyclotron resonance in semiconductors had just been observed; ferrites and permanent magnets were beginning to be understood; only a few physicists then believed in the reality of spin waves. Nanophysics was forty years off. In other fields, the structure of DNA was determined and the drift of continents on the Earth was demonstrated. It was a great time to be in Science, as it is now. I have tried with the successive editions of *ISSP* to introduce new generations to the same excitement.

There are several changes from the seventh edition, as well as much clarification:

- An important chapter has been added on nanophysics, contributed by an active worker in the field, Professor Paul L. McEuen of Cornell University. Nanophysics is the science of materials with one, two, or three small dimensions, where "small" means (nanometer 10^{-9} m). This field is the most exciting and vigorous addition to solid state science in the last ten years.
- The text makes use of the simplifications made possible by the universal availability of computers. Bibliographies and references have been nearly eliminated because simple computer searches using keywords on a search engine such as Google will quickly generate many useful and more recent references. As an example of what can be done on the Web, explore the entry http://www.physicsweb.org/bestof/cond-mat. No lack of honor is intended by the omissions of early or traditional references to the workers who first worked on the problems of the solid state.
- The order of the chapters has been changed: superconductivity and magnetism appear earlier, thereby making it easier to arrange an interesting one-semester course.

The crystallographic notation conforms with current usage in physics. Important equations in the body of the text are repeated in SI and CGS-Gaussian units, where these differ, except where a single indicated substitution will translate from CGS to SI. The dual usage in this book has been found helpful and acceptable. Tables are in conventional units. The symbol e denotes the charge on the proton and is positive. The notation (18) refers to Equation 18 of the current chapter, but (3.18) refers to Equation 18 of Chapter 3. A caret (^) over a vector denotes a unit vector.

Few of the problems are exactly easy: Most were devised to carry forward the subject of the chapter. With few exceptions, the problems are those of the original sixth and seventh editions. The notation *QTS* refers to my *Quantum Theory of Solids, with solutions by C. Y. Fong; TP* refers to *Thermal Physics, with H. Kroemer.*

This edition owes much to detailed reviews of the entire text by Professor Paul L. McEuen of Cornell University and Professor Roger Lewis of Wollongong University in Australia. They helped make the book much easier to read and understand. However, I must assume responsibility for the close relation of the text to the earlier editions, Many credits for suggestions, reviews, and photographs are given in the prefaces to earlier editions. I have a great debt to Stuart Johnson, my publisher at Wiley; Suzanne Ingrao, my editor; and Barbara Bell, my personal assistant.

Corrections and suggestions will be gratefully received and may be addressed to the author by email to kittel@berkeley.edu.

The Instructor's Manual is available for download at: www.wiley.com/college/kittel.

Charles Kittel

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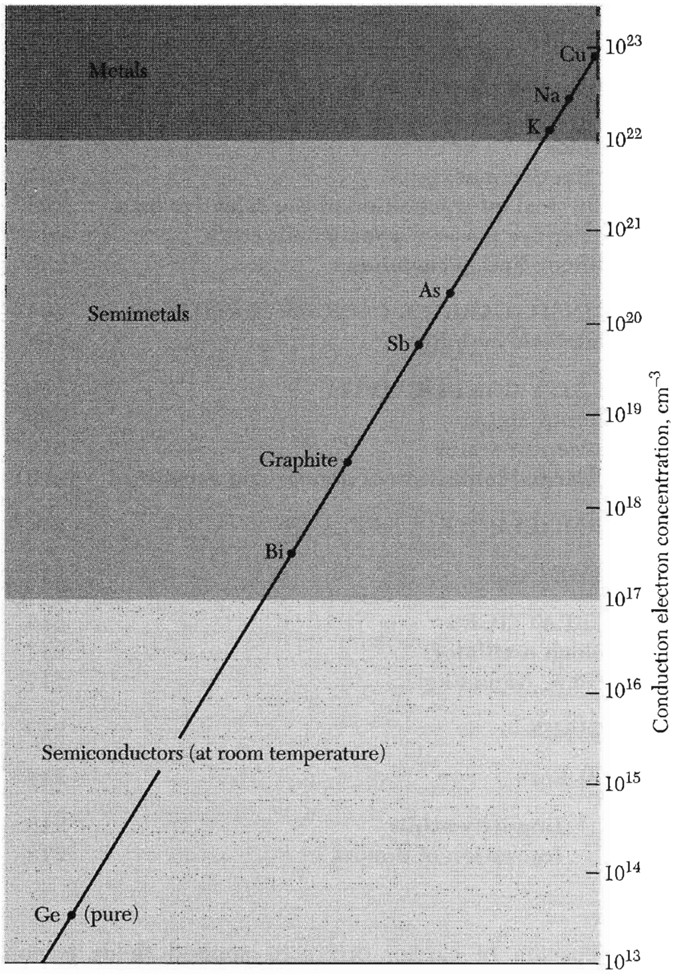

Figure 1 Carrier concentrations for metals, semimetals, and semiconductors. The semiconductor range may be extended upward by increasing the impurity concentration, and the range can be extended downward to merge eventually with the insulator range.

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NOTATION: In this chapter B_a denotes the applied magnetic field. In the CGS system the critical value B_{ac} of the applied field will be denoted by the symbol H_c in accordance with the custom of workers in superconductivity. Values of B_{ac} are given in gauss in CGS units and in teslas in SI units, with $1\ \mathrm{T} = 10^4\ \mathrm{G}$. In SI we have $B_{ac} = \mu_0 H_c$.

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NOTATION: In the problems treated in this chapter the magnetic field B is always closely equal to the applied field B_a, so that we write B for B_a in most instances.

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NOTATION: (CGS) $B = H + 4\pi M$; (SI) $B = \mu_0(H + M)$. We call B_a the applied magnetic field in both systems of units: in CGS we have $B_a = H_a$ and in SI we have $B_a = \mu_0 H_a$. The susceptibility is $\chi = M/B_a$ in CGS and $\chi = M/H_a = \mu_0 M/B_a$ in SI. One tesla = 10^4 gauss.

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NOTATION: In this chapter the symbols B_a and B_0 refer to the applied field, and B_i is the applied field plus the demagnetizing field. In particular we write $\mathbf{B}_a = B_0\hat{\mathbf{z}}$. For CGS readers it may be simpler to read H for B whenever it occurs in this chapter.

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NOTE: The text and problems of this chapter assume facility in the use of electromagnetic theory at the level of a good senior course.

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