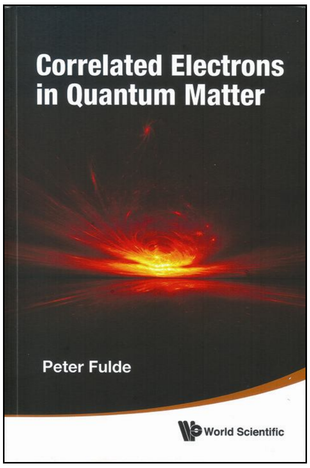


Correlated Electrons in Quantum Matter. Peter Fulde. World Scientific Publishing Co Pte Ltd, 5 Tok Tuck Link, Singapore 596224. 2012. xiii + 535 pp. Price: US$ 68.

Most phenomena that we experience in daily life can be traced to the collective behaviour of a large number of electrons in the things around us. It is the physical understanding of the behaviour of a collection of electrons which resulted from several decades of research that has enabled, for example, the electronics revolution that began about 50 years ago and is going strong even today. Electrons are fermions endowed with mass, spin and charge. Their motion can be influenced by application of external electromagnetic fields that couple to their charge and/or spin. Being fermions, electrons obey the Pauli exclusion principle that keeps two up-spin electrons apart even while imposing no restrictions on the relative motion of two opposite spin electrons. And being very light (small mass) particles, the quantum nature of electrons manifests in a vivid manner even in common metals such as copper. 'Quantum matter', a term which aptly refers to such an assembly of many electrons as in a metal, now encompasses other realizations of large collections of particles with quantum effects, including those realized in cold atomic systems.

Study of 'correlated' quantum matter is a forefront research area of condensed matter physics, promising not only many new emergent phenomena from collective behaviour, but also many technological sops with revolutionary potential, such as high-temperature superconductors and quantum computers. 'Correlations' is a term used broadly to indicate situations where motion of particles (electrons) is influenced not only by the Pauli principle but also by the interactions between them. Correlations produce a zoo of intriguing phases of quantum matter from spin liquids to fractional Hall states. The book under review is a welcome addition to the literature on this beautiful subject.

In this book, the author, an eminent condensed matter physicist, aims to present a bird's-eye view of the subject of electron correlations, including a discussion both of the basics and the most recent developments. This difficult task is achieved using shortened discussions from author's earlier book *Electron Correlations in Molecules and Solids* (Springer, 1995, 3rd edn) and inclusion of a variety of topics from transition metal oxides to fractional excitations that emerge in strongly correlated systems. In the author's own words, 'It is the sincere hope that the book might help some graduate students gain access to this fascinating field of theoretical physics'.

The 15 chapters of the book can be put into 3 groups. The first five chapters consists of introductory material, and a discussion of the theoretical approaches to the problem of determination of the electronic structure of materials. The second set of five chapters discusses approaches and theory of correlated electrons, including the theoretical treatment of established models of the field. The last five chapters deal with systems with correlations, including the well-studied transition metals to the most recent oxide superconductors. These chapters are supported by a set of ten appendices, many of which present short surveys of technical/calculational aspects. There is also included a useful list of acronyms immediately following the table of contents and an index at the end of the book. There are more than 500 references to journal literature over a period spanning nearly 80 years.

The book begins with an introduction to the subject of correlation; the author draws from his vast experience to start from the simplest hydrogen molecule and develops the discussion to the pnictides (the youngest members of the correlated family) in a fashion that not only elucidates the central ideas of the field, but also its difficulties and promises. The second chapter contains a treatment of the independent electron approximation (also known as mean field theory), including a nice discussion of aspects missing in this approach. An important, highly researched, topic of interacting electron theory, the homogeneous electron gas with Coulomb interactions (the jellium model) is discussed in the third chapter. The gist of the physics at both high (metallic state) and low densities (Wigner crystal) is brought out clearly, and techniques such as the random phase approximation are introduced. Chapter 4 logically follows up this discussion with methods for the realistic treatment of interactions and lattice potential using density functional theory. The chapter also contains a discussion of the more recent developments such as time-dependent/adiabatic formulations of density functional theory. Chapter 5 contains a summary of another set of methods which the author calls 'wave function based approaches' that is effective for treating correlation effects. As the author clearly explains, these methods (e.g. the method of configuration interactions), which were pursued vigorously by the quantum chemistry community, can be fruitfully applied to the problem of correlations. He argues that methods used in various communities are indeed different approximations of the cumulant equations.

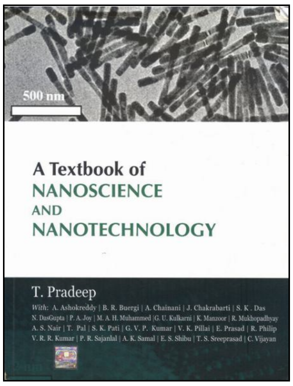
Chapter 6 contains discussions of the ground states of various systems from semiconductors to metals. The chapter points out that more sophisticated calculations (such as the complete active space self-consistent formalism) are needed to correctly describe systems with strong correlations. The next two chapters continue the logical development of subject with the discussion of excitations above the ground state. Quasi-particle excitations, including single-particle propagator, its properties and techniques for its calculation are discussed in chapter 7. This chapter also contains a treatment of the Landau Fermi-liquid theory of metals along with a discussion of quasiparticle excitations in semiconductor materials. Incoherent excitations are discussed in chapter 8 – this short chapter has some nice examples that clearly brings out the ideas behind this concept. Chapter 9 is yet another short chapter that deals with an approximate approach that can deal with disorder and correlations; a popular approach called the dynamical mean field theory is discussed in this chapter. Chapter 10 which deals with strongly correlated electrons is the most prominent chapter of the book. Spanning over 90 pages (nearly a fifth of the book), this chapter contains the key ideas, concepts and models of strong correlation physics. The chapter starts off with a very lucid discussion of correlation strength and emergent energy scales, and goes on to discuss various key models from the Anderson model to the *t–J* model (including its relation to the Hubbard model) and explores important physics such as the Kondo effect, metal–insulator transitions, etc. The chapter is replete with many theoretical techniques such as projection methods, slave particle methods, etc. These have come to be mainstays of the field, and a graduate student using this book would benefit tremendously with a careful study of this chapter.

The remainder of the book is a survey of systems with strong electron correlations. Chapter 11 discusses correlated transition metals, including a very readable discussion of their magnetism. This is followed by transition metal oxides in chapter 12, which includes a discussion of the structures and phenomena in cuprates, manganites, etc. Heavy quasiparticles that emerge in Kondo lattice and charge ordered systems are covered in chapter 13. Moving on to even more exotic emergent phenomena in correlated systems, the author discusses excitations with fractional charges in chapter 14. Systems discussed include polyacetylene, fractional quantum Hall effect and frustrated systems. The final chapter of the book is on superconductivity. Though there is a brief discussion of the standard BCS theory, the author's heart is clearly in the exotic superconducting avatars and effects. The final section of this chapter and the book discusses high-temperature cuprate superconductors. This choice for the final section seems quite apt as cuprates have provided some of the most perplexing problems of correlated electron physics.

The book touches upon almost all standard aspects of strong correlation physics, including many of the theoretical techniques (both analytical/numerical) and covers a wide range of experimental phenomena; it is in this sense unique and indeed is a commendable effort by the author. This book will certainly be useful to a practising condensed matter physicist as it can serve as a ready reference for theoretical concepts/techniques and phenomena of electron correlations. However, a fresh graduate student might find it hard using the book as a standalone textbook to study correlation physics. While parts of the book are readable (e.g. chapter 10), developments in the later part are a bit fast-paced. For example, it will be quite difficult to use chapter 15 for an introduction to superconductivity. The book will be most useful to those students who have already had an introductory course on many-body physics, and it can then play the role of an advanced text. Furthermore, the presentation of some of the topics appears to be too brief – for instance, the composite fermion theory of fractional Hall effect which has been so successful in explaining experiments has not been discussed (even though there is a brief reference). Yet, there is no doubt this book will be useful to an advanced graduate student and will whet her appetite for further exploration of strong correlation physics. On the same token, the book will be a wonderful resource for scientists from other fields such as theoretical/solid-state chemistry, physicists working on ultracold atoms interested in simulating condensed matter systems, string theorists exploring condensed matter problems using the gauge–gravity correspondence, etc.

VIJAY B. SHENOY

Centre for Condensed Matter Theory,
Department of Physics,
Indian Institute of Science,
Bangalore 560 012, India
e-mail: shenoy@physics.iisc.ernet.in



A Textbook of Nanoscience and Nanotechnology. T. Pradeep *et al.* Tata McGraw Hill, B-4, Sector 63, Noida 201 301. 2012. xxxiii + 949 pp. Price not mentioned.

During the past two decades, considerable research has been carried out in the field of nanoscience and nanotechnology. Nanomaterials of CdSe, CdSeS and CdSe/ZnS as white light-emitting phosphors, those of ZnO and SnO_2 as excellent gas sensors and photodetectors, doped carbon nanostructures as Pt-free catalysts for fuel cell applications, etc. have been developed that hold promise for potential applications. In addition, they are important for fundamental phenomena as well. For example, remarkable are the unique nanostructured materials such as carbon nanotubes that can be mechanically stronger than diamond and ferromagnetic materials exhibiting super paramagnetism when their size is reduced. Although several review articles and books on nanoscience and nanotechnology are available, the book under review has been designed to give a comprehensive understanding of the subject, starting from the fundamentals to application of nanostructures.

Synthesis of nanostructured materials is an integral part of nanoscience and nanotechnology. Similarly, characterization of nanostructures is of paramount importance. After giving a historical introduction to the subject, the book discusses the synthesis of various nanostructures using different techniques and various experimental tools to characterize them. A brief discussion on a variety of techniques such as scanning tunnelling spectroscopy, atomic force microscope and transmission electron microscope that allow us to probe the structure of matter with high spatial resolution, making it possible to see for instance individual atoms, has been presented. Techniques such as surface-enhanced Raman spectroscopy, electrochemical mass spectrometry, contact angle measurements, two/four probe conductivity measurements, zeta potential, etc. have also been discussed.

Several theoretical models with computational methods have been employed for understanding the nanoscale phenomena and novel properties of materials at nanoscale. One of the chapters is devoted to the theoretical understanding of nanostructured materials. The book also discusses advanced nanomaterials such as quantum clusters of gold that exhibit luminescence and magnetism in contrast with the bulk counterpart. The gold clusters are also chemically active and can be used as catalysts for oxidation and hydrogenation. Other advanced nanomaterials such as superlattices of