Preface

This book presents a collection of review papers on recent work in the related areas of strongly correlated systems, the effects of coherence on macroscopic systems and entanglement in quantum systems. These areas have attracted considerable interest not just due to their inherent complexity and unexpected nontrivial phenomena, but also due to their potential applications in various fields, from material science to information technology. We review topics in the fields of A) Strong Correlations, Transport and Dynamics in Complex Materials, B) Strongly Correlated Magnetic Systems, C) Quantum Coherent Systems and D) Quantum Entanglement.

It is well known that low dimensionality enhances quantum fluctuations and electron electron correlations. The first two chapters review the Luttinger Liquid paradigm in the context of the one dimensional Hubbard model, and some recent results on finite energy transport and spectral properties of this same model, based on the exact Bethe Ansatz solution. These have found striking confirmation in photoemission studies. Next, we review aspects of strong correlations in the cuprates and their manifestation in photoemission experiments, again, a major source of information for these materials. Following the discovery by the Manchester group of Andre Geim that two-dimensional carbon sheets (atomic monolayers of graphite) can be prepared in planar form and are remarkably stable, there has been a surge of theoretical and experimental activity on this remarkable material, graphene. Its properties are fascinating, even at the one-electron level, and the potential for applications (electronics, sensors, hydrogen storage) is enormous. We include an introduction to the basic physics of this most unusual material. The field of the quantum Hall effect is reviewed, in particular new and less familiar topics like the anomalous Hall effect. We conclude this part with two chapters on aspects of non-equilibrium phenomena such as in spin systems and in the context of the Falicov-Kimball model.

In the second part, spin systems in low-dimensional materials and the importance of the effects of disorder in spin systems are considered. Spin disorder is a particularly important ingredient in the transport and optical properties of manganites and hexaborides, the focus of Chapters 10 and 11. The field of transport properties in magnetic materials and their important potential applications in sensor technology are reviewed, paying special attention to the presence of magnetic domain walls and their effects on transport with a view on the growing field of spintronics.

In a third set of chapters we focus our attention on topics related to quantum coherence in fields such of Bose-condensation and superconductivity. We gather articles on atomic correlations in ultra cold quantum gases, and discuss developments on the theory of Bose condensation and its kinetic and dynamic properties. Also, several articles are dedicated to aspects of superconductors like the effect of singular density of states on the superconducting properties and effects of disorder. The importance of the interdisciplinarity of the concepts that emerged to understand superconductors and its relation to other branches of physics like chiral symmetry breaking is also addressed. The experimental capability of controlling cold atoms confined in small spatial regions, for instance with the use of optical lattices, has enabled the experimental observation of Bose condensation, the control of atomic configurations,and even of interactions, providing a very clean way to simulate various physical systems, like traditional correlated condensed matter systems. It also became possible to control, in a systematic way, quantum states, with possible applications in information technology. This establishes an interface between traditional condensed matter or atomic physics problems with the fourth part of this book dedicated to entanglement and its possible applications.

In this last part of the book we take a look at some of the recent developments in quantum information and computation and their relation to condensed matter physics. Entanglement was recognized, very early in the development of quantum mechanics, as the characteristic feature which enforced its entire departure from classical physics, but it remained, for a long time, as something strange or at least mysterious. Later, after the introduction of Bell's inequalities and their experimental verification, it started to be considered as a useful resource for quantum information and computation, for example, increasing our understanding of quantum mechanics, and even of nature. More recent advances not just in quantum optics but also in macroscopic quantum coherent systems, such as those discussed in part 3, have led to a reanalysis of several known results in condensed matter physics and to the development of new methods and techniques, in a fruitful cooperation between quantum information and computation theory and condensed matter physics.

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