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## BOOK REVIEW

# Quantum Physics in One Dimension

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To a casual ostrich the world of quantum physics in one dimension may sound a little one-dimensional, suitable perhaps for those with an unhealthy obsession for the esoteric. Nothing of course could be further from the truth. The field is remarkably rich and broad, and for more than fifty years has thrown up innumerable challenges. Theorists, realising that the role of interactions in 1D is special and that well known paradigms of higher dimensions (Fermi liquid theory for example) no longer apply, took up the challenge of developing new concepts and techniques to understand the undoubted peculiarities of one-dimensional systems. And experimentalists have succeeded in turning pipe dreams into reality, producing an impressive and ever increasing array of experimental realizations of 1D systems, from the molecular to the mesoscopic---spin and ladder compounds, organic superconductors, carbon nanotubes, quantum wires, Josephson junction arrays and so on.

Many books on the theory of one-dimensional systems are however written by experts for experts, and tend as such to leave the non-specialist a touch bewildered. This is understandable on both fronts, for the underlying theoretical techniques are unquestionably sophisticated and not usually part of standard courses in many-body theory. A brave author it is then who aims to produce a well rounded, if necessarily partial, overview of quantum physics in one dimension, accessible to a beginner yet taking them to the edge of current research, and providing en route a thorough grounding in the fundamental ideas, basic methods and essential phenomenology of the field.

It is of course the brave who succeed in this world, and Thierry Giamarchi does just that with this excellent book, written by an expert for the uninitiated. Aimed in particular at graduate students in theoretical condensed matter physics, and assuming little theoretical background on the part of the reader (well just a little), Giamarchi writes in a refreshingly relaxed style with infectious enthusiasm for his subject, and readily combines formal instruction with physical insight. The result is a serious, pedagogical yet comprehensive guide to the fascinating and important field of one-dimensional quantum systems, for which many a graduate student (and not a few oldies) will be grateful.

The first half of the book, chapters 1--5, is devoted to a coherent presentation of the essential concepts and theoretical methods of the field. After a basic introduction to the unique behaviour of interacting electrons in one dimension, and to early fermionic approaches to the problem,

Giamarchi turns to the technique of bosonization, introducing chapter 3 with a Marxist quote: 'A child of five would understand this. Send for a child of five.' This most powerful technique is presented in a step by step fashion, and serious perusal of the chapter will benefit all ages since bosonization is used extensively throughout the rest of the book. The same is true of chapter 3 where a phenomenological and physically insightful introduction is given to the Luttinger liquid--the key concept in the low-energy physics of one-dimensional systems, analogous to the Fermi liquid in higher dimensions. Chapter 4 deals with what the author calls 'refinements', or complications of the sort theorists in particular welcome; such as how the Luttinger liquid description is modified by the presence of long-ranged interactions, the Mott transition ('we forgot the lattice Gromit'), and the effects of breaking spin rotational invariance on application of a magnetic field. Finally chapter 5 describes various microscopic methods for one dimension, including a brief discussion of numerical techniques but focussing primarily on the Bethe ansatz--the famous one-dimensional technique others seek to emulate but whose well known complexity necessitates a relatively brief discussion, confined in practice to the spin-1/2 Heisenberg model.

In the second half of the book, chapters 6--11, a range of different physical realizations of one-dimensional quantum physics are discussed. According to taste and interest, these chapters can be read in essentially any order. Spin systems are considered in chapter 6, beginning with spin chains---Jordan--Wigner, the bosonization solution---before moving to frustration, the spin-Peierls transition, and spin ladders; and including experimental examples of both spin chain and ladder materials. Chapters 7 and 8 deal with interacting lattice fermions, the former with single chain problems, notably the Hubbard,  $t$ - $J$  and related models; and the latter with coupled fermionic chains, from finite to infinite, including a fulsome discussion of Bechgaard salts (organic conductors) as exemplars of Luttinger liquid behaviour. The effect of disorder in fermionic systems is taken up in chapter 9, and here the reader may react: interacting systems are tough enough, why make life harder? But disorder is always present to some degree in real systems---quantum wires, for example, discussed briefly in the chapter---and its effects particularly acute in one dimension. It simply cannot be avoided, even if the problem of interacting, disordered one-dimensional systems is still a long way off being solved. The penultimate chapter deals with the topical issues of boundaries, isolated impurities and constrictions, with a primary focus on mesoscopic examples of Luttinger liquids, notably carbon nanotubes and edge states in the quantum Hall effect. Finally 'significant other' examples of Luttinger liquids, namely interacting one-dimensional bosons, are considered in chapter 11; which concludes with a discussion of bosonization techniques in the context of quantum impurities in Fermi liquids---the x-ray, Kondo and multichannel Kondo problems.

The quality of the product attests to the fact that writing this impressive tome was a labour of love for the author. Anyone with a serious interest in getting to grips with one-dimensional quantum systems simply needs the book on their shelves---and will have great fun reading it too.

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