"Physics in Canada" Book Review
"La Physique au Canada" Critique de livre

"Field Theories of Condensed Matter Physics" Second Edition, by Eduardo Fradkin, Cambridge University Press, 2013, pp: 852, ISBN: 978-0-521-76444-5, price: 120.95

Eduardo Fradkin's book *Field Theories of Condensed Matter Physics* is a massive rewriting and modernization of the first edition. Over twenty years elapsed between the two (they were published in 1991 and 2013), and obviously a lot has happened in condensed matter physics since that time. (To name but one example, the entire field of topological insulators is currently a very hot topic, and it is only about ten years old.) The book is a substantial work, with 17 chapters spanning 800 pages. It is definitely not in competition with standard condensed matter physics books (such as *Many-Particle Physics* by Mahan); indeed, there is no discussion whatsoever of standard foundational topics such as Fermi liquid theory. The book would probably be useful to students and researchers who are already quite comfortable with either many body theory or quantum field theory.

The book strikes me as more of a Special Topics book than a textbook, although a Google search turns up many graduate courses for which the book seems to be used either as the main textbook or as a reference.

The first edition contained the following topics: the Hubbard model, magnetic instability, 1d quantum antiferromagnets, sigma models, spin liquids, chiral spin states, anyon superconductivity and the quantum Hall effects (integer and fractional). All of these are retained in the second edition; in many cases the chapter is left essentially intact (with errors corrected), while in others substantial revisions have been implemented. The only subject among these whose presence in the second edition surprises me is anyon superconductivity, a beautiful application of anyons but one which, as far as I am aware, is not observed in nature.

The second edition adds the following subjects: the renormalization group (eluded to at various places in the first edition), Luttinger liquids, sigma models, gauge theories, topological fluids, edge states, topological insulators and quantum entanglement.

The tone of the book is set right from the start. The first item on the menu is the Hubbard model. It is not easy reading! You should be prepared to roll up your sleeves before you delve into it. But the discussion is clear and thorough, so your work will be well rewarded. The discussion of symmetries is particularly nice.

The next chapter applies mean field theory to the Hubbard model, and discusses path integrals applied to it. It is a pretty whirlwind presentation of path integrals for those who have not already seen them; of course, many books and other references discuss path integrals in great pedagogical detail so it is not hard to fill in the gaps if necessary.

The next chapter takes on the renormalization group. Fradkin cites John Cardy's book as an inspiration; I find Fradkin's discussion very condensed and actually would recommend Cardy's book to anyone who finds Fradkin too telegraphic on this subject.

Jumping ahead, the penultimate chapter (almost a hundred pages in length!) discusses topological insulators, introducing the subject by drawing a number of parallels: with the quantum Hall effect, the spin quantum Hall effect, and even solitons in polyacetylene, fractional quantum numbers, etc. These all are topological in nature, and serve as a sort of warm-up for the main subject of the chapter.

The final chapter is on quantum entanglement, a subject which is relevant to a huge number of phenomena, from black holes to quantum information. At first sight, one might think it has little connection with the rest of the book (at least, that is what I thought), but Fradkin points out that topological phases are intrinsically nonlocal, so measures of non-locality such as quantum entanglement are in fact natural theoretical tools. He discusses several distinct applications: conformal field theory, various other field theories, holography and, finally, topological phases.

In summary, the book covers a number of interesting and important recent applications of field theory to condensed matter systems; it is at times not so self-contained (though Fradkin goes to great lengths to provide references; the bibliography is over twenty pages in length!). Advanced graduate students and researchers interested in the subjects covered will find the book rewarding if they are adequately prepared for it. But it is definitely not for the faint of heart.

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