“Physics in Canada” Book Review
“La Physique au Canada” Critique de livre

“Feynman Diagram Techniques in Condensed Matter Physics”, by Radi A. Jishi, Cambridge University Press, 2013, pp: 400, ISBN 978-1-107-02517-2, price: 111.95.

The iconic Feynman diagrams are almost synonymous with particle physics but over time, these convenient pictorial representations of mathematical expressions have actually proved to be ubiquitous in condensed matter physics as well. As the saying goes, a picture can tell a thousand words or at the very least least, a few lines of equations. With lucid explanations and elaborate examples, Jishi writes about these diagrams and their applications in a volume that is both detailed and accessible to undergraduate students in their senior year, perhaps after an introductory course in solid state physics.

The monograph is well-organized, progressively building up at a reasonable pace on an overture of the second-quantized Hamiltonian formulation. For several students, including myself, the first encounter with second quantization is in Gerald Mahan’s treatise, which, although a classic in its own right, hardly does justice to it. On the other hand, Jishi’s elucidation of the topic is a meticulous composition starting with a prelude of properly symmetrized wavefunctions and culminating in a coda of creation/annihilation and field operators. The text hints at the diagrammatic methods to come while demonstrating two-particle interactions as a scattering process (Fig. 3.5). The necessity of Feynman diagrams is underscored shortly thereafter by the jellium model and its associated problems in performing perturbative expansions owing to the divergence of higher-order terms. At this point, the discussion requires the introduction of the Green’s function formalism and having expounded the mathematics thereof, the discourse proceeds to certain standard topics in many-body physics such as linear response theory, the Kubo formula and the fluctuation-dissipation theorem. However, it is only with the introduction of the imaginary-time correlation functions in Chapter 8 that the foundations for the crux of the subject matter are laid. The treatment of Wick’s theorem, in the context of a perturbation expansion of the imaginary-time Greens functions, is particularly noteworthy in its illustration of Wick contractions and their diagrammatic representations by a felicitous example of first-order interaction in a system of pairwise-interacting fermions. Following this thread, the author deftly analyzes second-order corrections to the same subsequently and in doing so, formalizes the diagram rules, thereby essentially rendering the once tortuous calculations algorithmic.

A recurrent motif that pervades the book is the emphasis on topics of modern interest. A notable example would be graphene, which presents itself not only in several problems [2.4–2.6 (band structure and density of states), 3.2 (tight-binding Hamiltonian), 5.2 (vacancies and interstitials)] but also in case studies such as those pertaining to the calculation of its dielectric function or the spectral density function of a system consisting of an atom adsorbed on it. The discussion on

superconductivity, especially within the framework of the Green's function approach, is another most-welcome inclusion. Such efforts on the part of the author certainly help to familiarize the reader with the present directions of research and emphasize the relevance of the subject itself.

Despite its delightful approach, the book suffers from a few minor drawbacks which one cannot help but notice. The brief exposition of quantum mechanics, band theory and statistical physics in the initial chapters is too terse to be of practical use to the uninitiated learner. Since the author already presupposes some background knowledge in these fields, this introduction, presumably intended as a handy review, is largely redundant and could have been excluded without compromising on coherence. Secondly, the introduction of the various correlation functions and Green's functions in Chapter 6 is uncharacteristically confusing. Instead of putting the cart before the horse while introducing what is rightly termed as "a plethora of functions" in a rather ad hoc fashion, the arguments could have been better motivated from a physical perspective. Furthermore, several important results have been relegated to the exercises, most prominently, the Kramers-Kronig relations (6.11) and the method of analytic continuation (8.8) for obtaining the real-time retarded Green's function from its imaginary-time counterpart. However, these shortcomings do not take much away from the otherwise excellent treatment and such quibbles aside, I would definitely recommend the book to anyone desirous of marvelling at the beauty and pragmatic applicability of Feynman diagrams in the realm of condensed matter physics.

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