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Book Review: *Introduction to Mesoscopic Physics*

Introduction to Mesoscopic Physics. Y. Imry, Oxford University Press, 1997.

The word "mesoscopic" was coined in 1981 by a statistical physicist (N. G. van Kampen) to describe systems intermediate between the microscopic world of atoms and molecules and the macroscopic world of every-day life. Systems at this borderline, typically of sub-micrometer size, have unusual properties, that could not be expected by extrapolation from larger or smaller length scales. Some of the most interesting properties are universal, depending only on fundamental constants and not on parameters of the material: For example, the conductance of a metal wire fluctuates as a function of magnetic field by an amount e^2/h, independent of the mean value. The same quantum e^2/h appears in the step wise increase of the conductance of a point contact as a function of its width.

These, and other, experimental discoveries have led to a deeper understanding of basic notions as phase coherence and dephasing, scattering and dissipation, and the significance of time-reversal symmetry. A key role in these developments was played by Yoseph Imry, who has now written a book to share his insights. The time is right. Mesoscopic physics has reached a certain maturity, and many universities have included it as a course topic. It makes indeed a wonderful subject for students, since it provides a real-life application of what they have learned in their quantum mechanics courses. Imry's book is the first comprehensive introduction to the field.

The first half is devoted to transport through disordered metals, in particular to the phenomenon of localization. The treatment is based on two fundamental relations, the Thouless formula (relating the conductance to the broadening of energy levels) and the Landauer formula (relating the conductance to the transmission matrix). The Thouless energy (the inverse dwell time of an electron in the system) appears as the fundamental energy scale for quantum interference effects. Most of these effects involve transport properties, since these are able to probe the system on small energy scales (limited only by the temperature). The chapter on mesoscopic effects

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in thermodynamic properties centers on the persistent current flowing in small metal rings, predicted by Imry with R. Landauer and M. Büttiker in 1983, and observed in experiments a few years ago. That chapter concludes with one of the main unsolved problems of the field: The underestimate by an order of magnitude of the theoretical prediction.

The second half of the book contains three separate topics: The quantum Hall effect, mesoscopic superconductivity, and noise in mesoscopic systems. The quantum Hall effect does not require a small system, but is linked to mesoscopic physics by the conductance quantum e^2/h. Since there exist introductory text books devoted entirely to the quantum Hall effect, I would have preferred to find a chapter on single-electron tunneling and/or ballistic transport, two topics which are more at the center of the field but not included. The chapter on superconductivity in small systems deals with a subject of great current interest: The phase-conjugating properties of a superconducting interface drastically enhance the effect of interference on the conductance of a normal metal.

In conclusion, this is an excellent introduction to a new field of physics. It should appeal to teachers looking for a course that crosses the boundaries between traditional courses on statistical mechanics, quantum mechanics, and solid-state physics. I plan to use it myself for such a course in the near future. More advanced researchers will benefit from Imry's insightful qualitative explanations. A complete and up-to-date list of references provides a starting point for a more detailed understanding.

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Book Review: *Van der Waals and Molecular Science*

Van der Waals and Molecular Science. A. Ya. Kipnis, B. E. Yavelov, and J. S. Rowlinson, Clarendon Press, Oxford, 1996.

Among 19th-century founders of statistical-molecular physics, several, such as Maxwell, Boltzmann, and Gibbs, have been the subject of book-length biographies and historical articles analysing their work. Comparatively little has been written in English about Johannes Diderik van der Waals (1837–1923), though his name is well known to most physical scientists since he was the most successful in relating kinetic theory to the properties of real fluids.

In 1985, two Russians, A. Ya. Kipnis and B. E. Yavelov, published a biography of Van der Waals, on which they had worked for many years in almost total geographical isolation. The present book is an English translation from the Russian. J. S. Rowlinson, who recently published an English translation of Van der Waals's thesis,[1] participated in this translation of the Russian biography and contributed substantially to the treatment of the scientific aspects of Van der Waals's life work. These three authors have composed a truly remarkable book. As a biography, it goes well beyond the customary description of a subject's young years, studies, scientific career, major achievements, honors and impact. Based on an extraordinarily extensive set of references, many of them in the Dutch language, and many of them private communications from Dutch sources, the authors paint a picture of Dutch society in the 19th century as it set the stage for Van der Waals's life. In the process, the authors highlight the political and educational factors that made Holland in the second half of the 19th century such a fertile ground for science.

Before the 1850s, wealthy burghers would send their sons to the Gymnasium for a secondary, college preparatory education with heavy emphasis on the classics. In the middle of the 19th century, however, the growth of a vigorous middle class called for public secondary education of boys that was more practically oriented. A new type of high school, the Hogere Burgerschool (HBS), which stressed the teaching of mathematics

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and science, was founded and quickly became very popular. For University-trained mathematicians and scientists, the HBS offered prestigious, well paid teaching jobs. These teachers, in turn, made sure their subject matter was taught at a high level.

The authors describe the symbiosis between HBS and University, which channeled gifted youngsters into the sciences, resulting in a flood of outstanding scientists, as well as a new crop of superbly trained teachers. The reader cannot help but wonder what effect emulation of this 19th-century Dutch model of high-school teacher education would have on the state and status of mathematics, science and technology in those countries where high-school teachers presently do not have an academic-level background in their subject matter.

The book portrays in detail and with an incredible diversity of source material, photographs and references the 19th-century Dutch society that produced not only Van der Waals, but also Zeeman, Lorentz, Van 't Hoff, and Kamerlingh Onnes, all to be Nobel Prize winners.

Van der Waals began his career as an elementary schoolteacher's helper in his home town, Leiden, at the age of 15. He worked his way up as a teacher in the HBS system, while continuously improving his qualifications by taking university-level classes in science and mathematics. He obtained his Ph.D. at age 37; P. L. Rijke, Professor of Physics at Leiden University, was his official dissertation supervisor, called "promotor," but Van der Waals apparently conceived and carried out his doctoral research on his own initiative, inspired by the publications of Rudolf Clausius. By 1877 his work had won international recognition and he obtained a chair at the newly founded Municipal University of Amsterdam, where he taught until his retirement in 1908.

There is a thorough treatment of the background and methods employed by Van der Waals in deriving his equation of state, with a basis in the theory of capillarity and in kinetic theory. The book emphasizes his strong sense of the reality of molecules, his combination of intuitive insight and rigorous mathematics, and his ability to produce estimates of molecular dimensions in an age when reliable methods for determining such parameters (as well as the value of Avogadro's number) were just being developed, and molecules, to some scientists, were figments of the imagination. Other scientists accepted the reality of molecules but supposed them to have different properties in the gaseous, liquid, and solid states; Van der Waals was the first to show that a unified theory of different states of matter could be based on a single molecular model.

The impact of Van der Waals's thesis, due in no small manner to a qualifiedly positive review by Maxwell, is well documented in the book, which also describes the somewhat strained relations with Thomas

Andrews, whose experiments provided the first quantitative test of gas-liquid transition theory. The authors also note that chemists were often more appreciative of Van der Waals's achievements in correlating and explaining the properties of multicomponent multiphase systems, while some mathematically-minded physicists complained about the weak logical links between theory and application.

In the 1870s and 80s, the groundwork was done for the four fundamental scientific achievements of Van der Waals: the equation of state, the law of corresponding states, the generalization to fluid mixtures, and the theory of capillarity. The book describes these achievements in depth.

Van der Waals had to devote himself to his scientific work while burdened by a crushing teaching load. In addition, as a member of the Royal Dutch Academy of Sciences, he served as Secretary for fifteen years, carrying responsibility for the Proceedings and for a number of projects on which the Dutch government consulted with the Academy. Thus he served on the Committee that saved Heike Kamerlingh Onnes's budding cryogenic laboratory in Leiden by determining that his handling of the compressed-gas cylinders constituted a safe practice.

In the chapter on the Teacher and his School, the crucial importance of his interactions with Kamerlingh Onnes, which enabled the successful liquefaction of helium, is stressed. The contributions of the mathematician D. J. Korteweg to the geometric formulation of the mixture free energy surface and its properties are highlighted. In this chapter, we see the ideas of van der Waals radiate to a group of physicists and chemists, such as J. J. van Laar, J. M. van Bemmelen, H. W. Bakhuis Roozeboom, F. E. C. Scheffer, F. A. H. Schreinemakers and A. Smits, who all made substantial contributions to the theory of phase equilibria in fluid and solids.

Van der Waals had a happy family life until the untimely death of his wife Anna, in 1881. Sadness pervaded the staid home of the widower raising the three younger children with the help of his oldest daughter. These family circumstances are tenderly described. Details are included about the son (Johannes Diderik Jr.) who followed his father's footsteps; and about the daughter Jacqueline who became a poet ("to most Dutch people, her name is probably better known than that of her father"), but preceded him in death.

Van der Waals retired at the age of 70, just a few days after helium was first liquefied in Leiden. Retirement did not change much his work habits or teaching. The crown on his scientific career was his reception of the 1910 Nobel Prize for Physics three years after his retirement, in 1910.

One of the chapters is devoted to Van der Waals's influence on Russian science. For the Western reader, this chapter opens a window to a little-known world. Of the work described here much is presently no more than a curiosity, and it takes some effort to extract the lasting contributions of D. P. Konovalov, G. N. Antonov, and I. R. Krichevskii. An ample list of references completes this chapter.

Chapter 11 on the evolution of Van der Waals's ideas to present-day molecular physics is a quite readable, somewhat more compact version of the substantial chapter which introduces Rowlinson's translation of Van der Waals's thesis.[1] In the section on the equation of state the historical development is given of the struggle to put the equation on a solid mathematical footing, and of the treatment of the hard-sphere repulsions, as well as the attractive forces now bearing Van der Waals's name. The section on capillarity is brief, the topic having been covered in Chapter 6. The principal message the authors convey is how thoroughly forgotten this masterful work has been. Unaware of Van der Waals's work, L. D. Landau and E. M. Lifshits, in 1935, recreated Van der Waals's results for the interface between two magnetic phases; so did J. W. Cahn and J. E. Hilliard in 1958 for the interface between fluid phases. The section on critical phenomena gives credit to Van der Waals and Van Laar for developing a Taylor expansion of the equation of stāte at the critical point. Present-day physicists attribute this expansion to Landau. The authors remind the reader that as early as the 1890s, Van der Waals derived what are presently called critical exponents for the coexistence curve, the critical isotherm and the surface tension; he was aware that there was a discrepancy between the measured exponents and those predicted by his equation of state. Again, these findings had to wait till the 1960s to be resurrected,[2] and to become part of the modern theory of critical phenomena.

A chapter on physical chemistry ends the book. Here the complexities of phase behavior of binary and ternary mixtures are expounded. The Van der Waals equation, as generalized by him to mixtures, possesses the awesome power of generating almost all experimentally known types of binary phase diagrams. Deriving those diagrams by means of uncanny intuition, geometric double-tangent contructions, and complex algebraic manipulations was a tremendous, almost inconceivable achievement of Van der Waals and his school in those days of limited computing power. The greatness of this achievement is somewhat obscured by juxtaposition with much material of more limited importance. Although the ample discussion of Konovalov's laws is not misplaced, it is hard to follow since the laws are not stated in the book.

One hesitates to voice criticism of a work so complete, so rich, and carried out under such difficult circumstances. The only wish one has is that the ample offerings of information were a bit more prioritized or focused, so the reader is led to the important amidst the trivial. There are occasional, but not overly many, slips in the spelling of Dutch words. The translation of the Dutch "Liberalen" as "Liberals" will make the former, nonconfessional believers in the free market and a limited government, turn in their graves. Denoting their opposition, the "Conservatieven," as "Conservatives" obscures the fact that "Conservatieven" were the members of confessional parties. These are, however, minor lapses in a book filled with nineteenth-century historical facts about a small, idiosyncratic country.

In summary, this book is a gold mine of information not just for readers interested in the life work of Van der Waals and its impact on molecular science, but also for those interested in the "Second Golden Age" of Dutch science in the period from 1850 to 1920. One cannot help but wonder why a pioneer like Van der Waals has failed to arouse the interest of Dutch historians of science. One cannot help but rejoice that two Russian and one British scientist have captured the greatness of this unglamorous, stubborn, private Dutch toiler.

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