Introduction—Atomic and Electron Fluids

This volume contains the lectures given at the fourth international Gordon Godfrey workshop held at the University of New South Wales in Sydney from 26 to 28 September 1994. This time our lecturers came from Germany, Italy, Japan, the United States and Vietnam, as well as of course from Australia. There was a total of seventeen lectures. The workshops are jointly organised by the School of Physics at the University of New South Wales and the Department of Theoretical Physics, Research School of Physical Sciences at the Australian National University and are held annually at the University of New South Wales in Sydney. Each workshop concentrates on a different and novel research area of current interest in condensed matter physics. The late Gordon Godfrey was an Associate Professor of Physics at the University of New South Wales who bequeathed his estate for the promotion and the teaching of theoretical physics within the university.

The subject for the workshop was the microscopic properties of classical and quantum fluids. As the workshop title indicates, fluids can be made up not only of atoms but also of electrons, as in the case of the conduction electrons in metals and semiconductors.

Liquids are in many ways more difficult to understand than their gaseous or solid counterparts, but there has been dramatic progress in our microscopic understanding of them in recent years. Quantum statistics adds another layer of complexity. Quantum liquids include the well known helium liquids, conduction electrons, electron–hole plasmas and the nucleons of nuclear matter found in the core of dense stars. Topological liquids in two-dimensional electron layers may also exist. These would obey neither Fermi nor Bose statistics but some intermediate fractional statistics.

In recent years a successful approach for dealing with the ground state properties of both classical and quantum liquids has been density functional theory. This exploits the Hohenberg–Kohn–Mermin theorem which states that the free energy of a system is a unique functional of the one-particle density. In this collection of lectures Ashcroft and Munakata discuss application of the density functional approach to classical systems and the transition from the liquid to the solid phase. Ullrich and Gross describe density functional theory for quantum liquids.

Hieu introduces us to some tantalising ideas on novel topological structures for quantum liquids. These concepts initially sprang from attempts to understand the fractional quantum Hall effect for two-dimensional electron liquid layers in semiconductors in the presence of an external magnetic field.

Use of numerical simulation techniques has greatly increased our understanding of liquids. Searles and Evans review questions of non-equilibrium molecular dynamics in classical liquids, Morriss and Rondoni give us an introduction to simulations of chaotic behaviour and Rapisardi and Senatore discuss numerical simulations of the quantum liquid-to-solid freezing transition.

Landau Fermi liquid theory was a great step forward in dealing with strongly interacting liquids of fermions. Neilson reviews this theory from the microscopic point of view. The recently proposed model of a marginal Fermi liquid is also discussed. This model sits at the breakdown point of the Landau Fermi liquid picture just where interactions between the fermions have become strong enough to destroy the Fermi surface. It has had some success as a possible mechanism for high transition temperature superconductors.

The lectures in the workshop have been selected to provide a representative coverage from recognised and active research leaders in the field and are aimed primarily at advanced graduate students. The best way to gain a perspective in a new field is through a balanced set of lectures and the discussions arising from them. This is what the workshops as a series attempt to do.

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