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BOOK REVIEW

J. M. Ortiz de Zárate, J. V. Sengers, Hydrodynamic Fluctuations in Fluids and Fluid Mixtures

Elsevier, 2006, 309 pp

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This beautifully written monograph provides a detailed treatment of thermally excited hydrodynamic fluctuations in fluids. The emphasis is on quiescent single-component fluids and binary mixtures subjected to a temperature gradient. Physically this situation is realized either when the imposed gradient is too small to induce convection or when a stabilizing gradient is imposed (usually by heating from above). Under these conditions, thermal fluctuations become very long-ranged, something that is not intuitively obvious. Some discussion of related systems, including fluctuations in liquid crystals below the onset of electro-hydrodynamic convection and in fluids subjected to shear, is also provided. A lucid and consistent style, thorough attention to detail, and an accurate and comprehensive set of citations ($\sim$400) to the original research literature make it a pleasure to read. It is essential reading for anyone involved in the field, either experimentally or theoretically, and could also serve as a text for a graduate level special topics course.

After obtaining the equations of fluid mechanics from conservation laws, the authors provide an elegant introduction to non-equilibrium thermodynamics with an emphasis on dissipative fluxes and entropy production. One chapter is devoted to calculating the correlation functions that characterize temperature and velocity fluctuations in a single-component fluid in thermal equilibrium. This serves to ground the reader, and introduces the method of fluctuating hydrodynamics used throughout the remainder of the book. This theoretical method introduces rapid, short range, stochastic forcing terms into the equations of fluid dynamics, to mimic the effects of random molecular motions corresponding to dissipative processes, such as heat conduction, on the slow

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hydrodynamic modes. Succeeding chapters gradually develop the subject, together with the mathematical techniques required.

Initially, a single-component fluid in a gravitational field and subjected to a temperature gradient is treated within the Boussinesq approximation, while ignoring boundary effects. The primary quantities of interest are the correlation functions related to quantities measurable via light scattering or the quantitative shadowgraph method. The effect of the gradient on both the Rayleigh line and the Brillouin doublet is elucidated. This serves to illustrate the two mechanisms leading to long-ranged correlations, namely, mode-coupling and spatially non-uniform stochastic forcing. The same level of treatment is then provided for binary mixtures.

Succeeding chapters address the effects of laterally infinite horizontal boundaries on the fluctuations, including both the more tractable "free-slip" condition and realistic "stick" boundaries. For both single-component fluids and binary mixtures, the boundaries are assumed to have a thermal conductivity much greater than that of the sample, and they are assumed impermeable for the mixture. In both cases, the methods required to obtain numerical solutions are outlined, and approximate analytical results realistic enough for comparison with experiment are obtained by means of zero-order Galerkin approximations for the vertical dependence of the relevant quantities.

The case of fluctuations below the onset of Rayleigh-Bénard convection, which is the subject of a considerable literature, is discussed in detail. The "most-unstable mode" approximation and the well-known Swift-Hohenberg model are introduced, and compared to the more exact calculations for both "free-slip" and "stick" boundaries. In addition, the wave vector for which the fluctuations have maximum amplitude enhancement and that for which the decay rate is minimal are investigated. The two wave vectors are found to differ systematically, converging only at the critical Rayleigh number.

The case of a binary mixture is considerably more complicated, with the behavior depending not only on the Rayleigh number, but on a second control parameter as well (the separation ratio). This system is again treated using a zero-order Galerkin approximation, and results are presented for both the concentration and the temperature fluctuations, for the case of positive separation ratio.

One chapter is devoted to experiment. The two most relevant techniques, light scattering and the quantitative shadowgraph, are described, and the relationship between the measured quantities and the theoretical results is made clear. Many of the existing experiments are discussed and compared with theory, both for the Rayleigh-Bénard system and binary mixtures.

In addition to presenting a unified treatment of the subject, the book takes considerable pains to relate the results to much of the existing literature. Thus, it serves to place a great deal of work into a well-defined context.