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## BOOK REVIEW

**Thermal convection: patterns, evolution and stability**, by Marcello Lappa, John Willey & Sons Ltd., 2010, XIII+670 pp., £150, \$215, €172.50, hardback (ISBN-13: 978-0-470-69994-2), online (ISBN-13: 978-0-470-74998-2), ebook (ISBN-13: 978-0-470-74999-9).

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At the turn of the last century Henry Bénard produced his famous picture of the hexagonal flow pattern observed in a thin layer of spermaceti heated from below. Ever since thermal convection, in its various forms, has been a subject of continuously expanding research. This interest is well-justified as thermal convection is, possibly, the most common type of fluid flow in nature. In addition to their numerous small scale manifestations, convective motions mix stellar interiors and planetary atmospheres and oceans, they drive tectonic plates and generate planetary magnetic fields. In industrial applications, thermal convection enters wherever heat transfer is involved. In nuclear reactors and ovens, in crystallisation processes and casting, convection plays a crucial role. Thermal convection is important on a more fundamental level as well. It is one of the simplest and most easily controlled non-equilibrium systems, and as such it is a testbed where many theoretical and experimental methods for the study of pattern formation in spatially extended systems and for the transition to turbulence have been developed. The present monograph has as its main aim to give a comprehensive but, at the same time, coherent account of thermal convection, starting with two of its basic types — convection due to temperature dependence of density of fluids placed in a gravitational field and convection due to temperature dependence of surface tension — and proceeding to include a large number of settings in which these two basic cases may be combined. In my view, the author Marcello Lappa, of the Microgravity Advanced Research and Support Center, Italy, succeeds well in presenting a comprehensive account of the phenomenology, while his attempt

to provide a coherent theoretical framework is somewhat less convincing.

In the Preface the author makes his approach for achieving the aim of the book explicit: he is really concerned with creating a “critical, focused and comparative study of all these different types of thermal convection” (p. xvi), but he prefers to keep the mathematical language “to the minimum” (p. xvii). He is, though, well-aware of the importance of mathematical concepts, and in chapter 1 the governing equations of Fluid Dynamics and energy transport are derived from first principles. Several related methods of theoretical analysis are also briefly introduced here, namely linear and energy stability concepts and numerical approaches to the Navier–Stokes equations. The chapter also includes a discussion of some concepts of nonlinear dynamical systems, pattern formation and chaotic behaviour, as well as of Maxwell’s equations. In chapter 2 various aspects of gravity and surface tension, the forces responsible for the two main types of thermal convection considered in the book, are discussed. In connection with gravity, the Boussinesq–Oberbeck approximation is introduced while in connection with surface tension experiments on platforms orbiting in space are described. The chapter proceeds with a list of several well-known exact solutions of the Navier–Stokes equations for thermal problems, including Hadley and Marangoni flows in horizontal layers of infinite extent, and concludes with remarks on the effects of boundary layers. Chapter 3 provides several examples of thermal convection in nature and in industrial applications reflecting the biases of the author. With this concludes a rather extensive coverage of the basics, and there is then a sequence of chapters, each devoted to the discussion of a rather broad topic: the Rayleigh–Bénard problem (Ch. 4), dynamics of thermal plumes (Ch. 5), systems heated from the side (Ch. 6), convection in inclined layers (Ch. 7), thermovibrational convection (Ch. 8), Marangoni–Bénard convection (Ch. 9), thermocapillary convection (Ch. 10), mixed buoyancy–Marangoni convection (Ch. 11), hybrid regimes with vibrations (Ch. 12), and flow control by magnetic fields (Ch. 13). In each of these chapters, the author draws on the literature and describes in minute detail the relevant model and experimental configurations and discusses the effects that have been discovered as geometry, dimensions, boundary conditions, parameter values, secondary effects, etc., are varied. In line with the declared aims of the book, much effort has been expended to organize this empirical knowledge into a coherent body by discussing the physical nature of the related forces, by progressing from simpler idealized configurations to more realistic experimental setups, and by discussing sequences of bifurcations in the parameter space. This is done in the hope to gain insight by finding analogies and common physical mechanisms acting in seemingly different situations. At the same time, only elementary details of the

corresponding mathematical theory are given. While such comparative attempts to build a physical theory often help the intuition, they also have well-known and widely recognized conceptual limitations, and the book would have benefitted if more details of theoretical nature had been included. However, in defence of the author, it must be acknowledged that most of the interesting types of motion can even now only be qualitatively described rather than be analysed in mathematical terms. Having in mind this phenomenological approach to the topic, the most likely audience for this monograph are scientists and engineers working on industrial applications. However, the synthesis of such a large amount of detail in the text is also likely to attract the interest of theoreticians and experimentalists looking for new questions to attack.

A number of original results are included. Especially interesting are the numerous figures created from the author's own numerical simulations and specifically designed to illustrate various flow features presented in the main text. A minor irritation is the style of writing. While the use of English is generally good, one can find instances where words are not fitting very well. The book is rather voluminous. This is partly justified, in view of the wide range of phenomena that it covers, but some discussions run longer than really necessary, and some remarks are even redundant as numerous cross-references to other parts of the book are made. The conscious choice to avoid mathematical language certainly does not help to constrain the length of the text.

Since the author has been involved in problems of thermal convection in connection with the subject of crystal growth, and in microgravity environments these topics have received a detailed coverage. However, the readers of *Geophysical and Astrophysical Fluid Dynamics* may be disappointed that the topic of convection in rotating flows is not included in the monograph. This also is a minor inconsistency in the book, as many of the examples of thermally convecting flows mentioned in chapter 2 are chosen from the realm of geophysics, convection in the Earth's core and the geodynamo problem, atmospheric and oceanic convection and other planetary applications, in all of which the Coriolis force plays a crucial, even a dominant role.

One of the most attractive features of the monograph are its detailed index of terms and its extensive list of references. Nearly 1300 articles and books are cited which allow the reader to enter the literature in a very detailed way. However, in several instances the author has missed the opportunity to reflect a different point of view by citing other relevant monographs. For instance, the book by A.V. Getling "Rayleigh-Bénard convection: structures and dynamics", World Scientific (1998), provides a more theoretical perspective to the topic discussed

in chapter 4. Similarly the books “Thermal vibrational convection” by G.Z. Gershuni and D.V. Liubimov, Wiley & Sons (1998), and “Nonlinear dynamics of surface tension driven instabilities” by P. Colinet *et al.*, Wiley & Sons (2001), should be cited in relation to chapters 8 and 9, respectively. Also, the large list of references could become even more useful if the page would be indicated on which the reference is cited.

In summary, while the book falls short of presenting a coherent theoretical framework of thermal convection, it is a treasure-trove of phenomenological details ordered in a systematic way. It represents the most comprehensive single-volume monograph on convection phenomena available at the present time. I am glad to have the book on my shelf and I will recommend it to anyone with interest in convection as an inspiring guide through its myriad manifestations.

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