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REVIEWS

The Statistical Mechanics of Simple Liquids. By S. A. RICE and P. GRAY. Interscience, 1966. 582 pp. £7. 10*s*.

One of the classical aims of statistical mechanics is to give a complete description of the liquid state in terms of the microscopic forces which act between the individual molecules; to pass from the Lennard–Jones intermolecular potential to the equation of state, or from Schrödinger's equation to the Navier–Stokes equations. Rice and Gray's stimulating and comprehensive book sets out to provide a full account of the present state of the theory, with special emphasis on the study of transport processes in liquids.

Considerable progress has been made over the last twenty years in laying firm foundations for the theory of irreversible processes; the student of fluid mechanics will be reassured to discover that the foundations of non-equilibrium statistical mechanics are today as soundly based as those of the equilibrium theory. On the one hand Prigogine's penetrating analysis has cleared up the old 'irreversibility paradoxes', showing how the microscopic reversibility of molecular dynamics is compatible with the slow irreversible evolution of an ensemble towards thermal equilibrium. The Boltzmann equation for a dilute gas can now be deduced rigorously by infinite order perturbation theory without invoking time-smoothing or making repeated assumptions of molecular chaos between the collisons. On the other, Kubo's linear response theory has brought out the relation between transport processes close to equilibrium and the fluctuations in the equilibrium ensemble itself. The theoretician now knows that every transport coefficient is related to a well-defined autocorrelation function which is calculable in principle.

The practical problem of applying these firmly established principles to real fluids remains stubbornly resistant to attack, in spite of heroic efforts, and no final solution is in sight. Faced by the choice between a highly selective appraisal of the main lines of research, standing back from the technical details, or a complete line-by-line analysis of current theories, Rice and Gray have chosen the latter course. The result is a scholarly, accurate, but demanding text, which requires a strong mathematical digestion and a clear head. At times it reads more like an extended research paper than a book, so it is not for beginners.

After a brief introduction, chapter 2 sets off at a cracking pace through a highly detailed exposition of the equilibrium theory of dense gases and fluids. This takes about one third of the book, and contains 553 equations (some occupying several lines of print) in 155 pages. We first meet the Ursell–Mayer cluster expansions in the grand canonical ensemble, with graphs and cumulants; then switch to Kirkwood's approach through the hierarchy of integral equations for the reduced particle distribution functions. After a very full examination of the superposition approximation some more recent theories are introduced: Padé approximants, the hypernetted chain approximation, and the Percus–Yevick equation. The reader who can follow this coherent well-organized

account will be completely equipped to plunge into research; but a beginner may well miss the wood for the trees. The final section compares theoretical and experimental equations of state for liquid argon. The extent to which the major problems are still unsolved is brought out forcibly when one looks at the attempts to calculate radial distribution functions and compressibilities. The theory is only adequate at rather low densities.

Chapters 3 and 4 open the subject of the approach to equilibrium in a more physical way. There are nice accounts of the relation between irreversibility and coarse-graining, of the irreversibility paradoxes and Poincaré's recurrence theorem. Next comes a résumé of the theory of random processes, leading into a discussion of Brownian motion.

After this breathing space we plunge into a very technical chapter on the kinetics of molecular collisons in dense fluids, largely based on the author's own researches. A key feature of the theory is the separation of the molecular forces into a weak long-range attraction with a hard repulsive core. After time-smoothing one obtains a form of Boltzmann equation for the one- and two-particle distribution functions, with added frictional terms. The mathematical formalism is rather heavy, but seems to be necessary in order to progress to the core of the book, chapter 6.

Here at last one makes the connexion with fluid mechanics. The theory works back from the Navier–Stokes equations through the molecular distribution functions and kinetic equations to concrete expressions for all the transport coefficients. These turn out to be functions of the pair distribution function and the Brownian motion frictional coefficient. The actual application of the theory to liquid argon is an anticlimax; the agreement with experiment is disappointingly poor, and the authors confess themselves unable to assess the final position (p. 420). Clearly the statistical theory of liquids still has far to go before it loses its reputation as one of the most intractable branches of physics.

The book concludes more hopefully with a sketch of Kubo's linear response theory and Prigogine's perturbation analysis of the Liouville equation. This establishes that the underlying principles of the kinetic theory are consistent with those of non-equilibrium statistical mechanics, justifying in retrospect many of the *ad hoc* assumptions which one usually makes.

One day, when the final form of a successful statistical theory of liquids becomes clearer, one would like to see a brief critical and detached assessment of the subject, bringing out the parts of the theory which are here to stay. Till then, simple liquids remain far from simple, but Rice and Gray have given a fluent and expert progress report from the front line, which should be read by every serious worker in this field.

A. D. McLachlan

Etudes des Transferts en Mecanique des Fluides Monophasique. Tome 1: **Equations generales; similitudes.** Tome 2: **Couche limite; resultats experimentaux.** By M DOUCHEZ. Masson et Cie, 1965. Tome 1, 394 pp., 96 F. Tome 2, 416 pp., 98 F.

For a university teacher, it is always of interest to see the notes from which a colleague delivers his lectures. What topics does he present, and in what order? What are the starting points of his derivations, and in how much detail does he present them? Is he careful to contrive transition passages? And does he leave loose ends to encourage further study? To look into the lecture notes is to find at least partial answers to these questions; and, even if one finds nothing to copy, the contact with another mind, grappling with the familiar problems of presentation and compression, bestows some comfort and reassurance.

The two volumes under review provide this experience; for they have the form of lecture notes, with just enough text to enable the equations and the figures to be understood. There is an implication in the introduction that the lectures were initiated by Pro. A. Fortier, and that Prof. Douchez is acting as the Boswell to his Johnson (the Tietjens to his Prandtl would perhaps be more apt); but whatever its origin, the reader is regaled with an extended display of pedagogic skill. Probably most teachers of fluid mechanics and heat transfer can gain something from its perusal.

To judge from the Preface supplied by Prof. Fortier, the lectures represent a break from the French tradition of fluid-mechanics teaching, which has given rise to 'l'impression que la Mécanique des Fluides était confondue avec l'étude des fonctions analytiques et des transformations conformes'. Certainly, the transfer of momentum and heat in boundary layers occupies a large proportion of the work. The treatment is lucid and extensive, without being especially advanced; for example, though many topics are dealt with at the greater length which is suitable for absorption by students, there are perhaps none which do not feature, explicitly or by implication, in Schlichting's *Boundary Layer Theory*.

Having once mentioned Samuel Johnson, I can usefully recall that this eminent literary critic confessed that he rarely read any book to the end. No more have I scrutinized all of the 800 pages of Prof. Douchez's publication. I have admired some passages, disagreed with others, and flicked idly over the pages of those sections, for example, that on one-dimensional compressible flow, of which the theme was too familiar to excite interest; but even this negligent treatment revealed one idiosyncrasy of the author: he can't, or won't, spell foreign names. 'Karmann', and 'Schlichtin', were easy to identify. But who were 'Hatri' and 'Gorther'? Because, surprisingly, there is no list of references, I could not be sure. Once my vigilance for names had been awakened, I found other risibilities; for example, the heading: '(*a*) Petits Reynolds'. Poor little Reynolds! I thought. But then, what filling-station attendant remembers that 'diesel' was someone's name? Is it not indeed a mark of supreme recognition, to have one's name remembered, and one's person forgotten?

D. B. SPALDING

Advances in Heat Transfer. Volumes 2 and 3. Edited by J. P. HARTNETT and T. F. IRVINE. Academic Press. Vol. 2, 1965. 465 pp. $16.00 or £6. 8*s*. Vol. 3, 313 pp. £4. 16*s*.

The ten long articles in these two volumes vary greatly in subject, intention and quality. Some may serve, for several years, as sources of enlightenment and useful knowledge; but others will be referred to by their authors alone.

Each author has taken an aspect of heat transfer which is well known to him, and has attempted to describe its main features in a connected manner; but some authors seem not to have considered that the writer of a survey, since the elements of his material are bound to lack novelty, must offer his readers an alternative reward. Only the significant and durable parts of the subject should be included; they should be organized into an evident, natural, and preferably novel unity; and the language should be free from clumsiness and ambiguity.

As to language, a poor example is set by the carelessly worded preface, identical for both volumes save for the date. The literary style of the preface, but not its brevity, has been copied by the writers of the articles on heat transfer in liquid metals, in rapidly accelerating flows and in chemically reacting boundary layers. Here are some sample sentences. 'The most familiar of these applications today is their use as coolants in Nuclear Reactors, for which many of the available metals have the further desirable characteristic of favourable nuclear properties, and their potential use as working fluids in space power plants, for which small equipment size is necessary.' 'The possible influence of variable properties considerations are readily demonstrated by the closed-form approximation.' 'As was with the gas phase combustion discussed previously, the backward (endothermic) reaction is negligible, especially at the surface temperatures which are usually much lower than the temperatures of the gaseous flame zones.' The articles also lend support to the rule that care in the choice of words is usually accompanied by a tidy organisation and a considerate selection of material.

The review by Kestin, on the effect of free-stream turbulence on heat-transfer rates, possesses most of the merits which a review should have: the subject has practical and theoretical importance; current knowledge and outstanding problems have not been recently surveyed elsewhere; the author is qualified by his own researches to distinguish the significant from the merely interesting; and his writing is free from ambiguous constructions which recall the reader's eye to the start of the sentence. Also commendable, in a more competitive field, is the article by Westenberg, entitled 'Survey on dilute gas transport properties,'

The reviewer must declare an interest in Leont'ev's review of turbulent boundary layers, because he personally drew up the contract between the editors and the author, writing in grammarless Russian on a table napkin in a Minsk hotel. The subject is viewed from the special stand-point that prevails in Professor Kutateladze's institute in Novosibirsk; but it contains some interesting advances beyond the earlier monograph by Kutateladze and Leont'ev. The article describing the methods which are used at the Jet Propulsion Laboratory in Pasadena, for predicting heat transfer in rocket nozzles, is even more

restricted in its concepts; but this very limitation gives the article a unity which counteracts, to some extent, the pedestrian quality of the prose.

The straightforward and authoritative article by Metzner prompts some remarks which will serve to close this review. The article concerns heat transfer in non-Newtonian fluids, and takes the form of a critical survey of the literature. What is evident from this survey is the disproportion between the numbers of experimental and theoretical publications; the latter predominate because they are so easy to produce; yet the validity of the constitutive equations from which they start has been too little established. Surely this situation must soon change; for it is now *so* easy to solve the pipe-flow and boundary-layer equations that mere demonstrations of the ability to do so are becoming tedious. When this ability is widely shared, research workers can concentrate their efforts on the truly important task of describing, in differential terms, the relevant properties of the fluids.

D. B. SPALDING

Cours d'Oceanographie Physique. By H. LACOMBE. Gauthier-Villars, 1965. 392 pp. 90 F.

Until the publication of this book the only text available to French-speaking students was the somewhat outdated *Traite d'Oceanographie Physique* of Captain Rouch, published in the 1940s. The need for a modern text in French incorporating the progresses of the last twenty years was thus particularly pressing, and the *Cours d'Oceanographie Physique* more than adequately fulfills this need.

This book grew out of a course of lectures given by the author for the last fifteen years to students of the 'Ecole d'application du Service Oceanographique' and is at a level suitable for senior undergraduate or graduate students. In view of the context in which such lectures were given, it is perhaps not surprising that practical topics are given more emphasis than is usually the case in such a textbook. The author confesses his intention of writing a book somewhat halfway between a theoretical treatise and a technical manual: in short, a book for practicing oceanographers. Thus, after a chapter of introduction and another on the properties of sea water, there follows a chapter entirely devoted to measuring devices and ending with a detailed set of instructions on how to make standard hydrological observations at sea, account for wire angle, and process the collected data. One might easily argue that such techniques are best learned on the spot. This is, however, the only section where the 'technical' influence so clearly predominates. On the whole, however, the blend between theoretical and practical is a happy one, the subject is introduced in highly logical fashion and pleasantly described. The mathematical derivations are adequately complemented by more qualitative physical discussions and the text is abundantly illustrated. An effort has obviously been made to use actual observational material in the figures, rather than line drawings of hypothetical situations. The relatively large format (8 in. × 10 in.) leaves the text well aerated and easy to read. References are listed after each chapter for easy access rather than lumped at the end of the book. The presentation on the whole is of superior quality.

The bulk of the material treated falls into two sections: currents and waves. Nothing is said about tides or about the distribution of water properties in the oceans: these two topics form the subject of other lecture courses given concurrently with the author's course and may later find their way into book form! No preliminary knowledge of fluid dynamics is assumed, since two chapters are devoted to a discussion of the forces and energy sources in the sea, to a derivation of the hydrodynamical equations and to a short discussion of turbulent effects. The dynamic method of current calculation is presented in detail with practical examples, and its limitations are clearly pointed out. The discussion of circulation patterns in restricted basins barred with sills is, however, somewhat sketchy, and one deplores the absence of any material on estuarine circulation. The Ekman theory is presented in detail (perhaps too much so) and followed by a few pages on slope currents and longshore currents. The theory of wind driven ocean currents is treated coherently and extensively, but little is said on research postdating Munk's work. The subject of thermohaline circulation is treated somewhat summarily, but more about meanders is presented than is usually the case, including some interesting and little known results of Saint-Guily.

The classical material on surface wave theory is extensive and the section on wave generation includes discussions of the mechanisms of Miles and of Phillips. The discussion on statistical representation of the sea state and on sea-state prediction is perhaps more extensive than is warranted in an introductory text. The chapter on the influence of bottom topography on surface waves is extremely detailed, and even contains some problems which would be better put in a test on Coastal Engineering. The final chapter on wave measurements appears in comparison rather sketchy. It is regrettable that practically nothing is said about internal waves, except for their existence and as a source of error in dynamic calculations; that not a word is written about Rossby waves; and that a short discussion of non-linear interactions between waves and currents and other waves could not have been introduced along with the useful concept of radiation stress in the otherwise fairly comprehensive treatment of surface waves.

On the whole however the *Cours d'Oceanographie Physique*, because of the lucidity in which the chosen subjects are treated, the wealth of illustrative material and its judicious use and the excellent typographical presentation, is a text of considerable pedagogical value and compares favourably with the numerous English-language counterparts published in recent years.

As an added feature it brings out under one cover scattered and hitherto little known (at least to English speaking oceanographers) works of many French oceanographers, like that of Miche on waves, of Saint-Guily on meanders, Ekman theory and oceanic circulation, and of Lacombe himself on wave refraction and Mediterranean oceanography.

P. H. LEBLOND

SHORTER NOTICES

Eleventh Symposium (International) on Combustion. Published by the Combustion Institute, 1967. 1200 pp. $42.00.

This symposium was held at Berkeley in August 1966, and the texts of the nearly 100 contributed papers and the comments made on them in discussion have now been published in full. Fluid dynamics plays an important part in many of them, especially those on fire plumes and flame propagation, but it is not possible to summarize the contents.

Fifth Symposium on Naval Hydrodynamics: Ship Motions and Drag Reduction. Office of Naval Research, 1964. 1170 pp. $7.25.

This symposium, sponsored by the Office of Naval Research and the Skipsmodell-tanken, is one of a well-known series. The volume contains 26 substantial papers, many of which are on rather technical questions concerning the motion of a ship in the presence of waves and the influence of ship shape. Three of the papers are about the mysterious reduction of turbulent skin friction in water which results from the addition of various high-polymer substances.

Quantum Field Theory and Hydrodynamics. Edited by D. V. SKOBEL'TSYN. Consultants Bureau, Plenum Publishing Corporation, 1967. 283 pp. $7.50.

This paperback is a translation of the Russian original, volume 29 in the Lebedev Physics Institute series. The editor claims in the foreword that 'the methods of quantum field theory naturally penetrate into the hydrodynamics of relativistic systems and into statistical problems'. That may well be, but this collection of articles is nevertheless a rather unnatural juxtaposition of papers on quantum field theory on the one hand, and on certain somewhat esoteric topics in fluid mechanics on the other.

Heat and Mass Transfer in Process Metallurgy. Edited by A. W. D. Hills. Published by The Institution of Mining and Metallurgy, 1967. 252 pp. £3.

A collection of seven papers presented at a two-day symposium in London. They show the extent to which the principles of fluid dynamics and of heat and mass transfer are now being employed in the processing of metals. The papers are mostly rather technical, but those who are concerned with the mechanics of large gas bubbles in liquids will find some interesting material.

Atmospheric Turbulence and Radio-wave Propagation. Edited by A. M. YAGLOM and V. I. TATARSKY. Publishing House Nauka, 1967. 374 pp. 2.25 roubles.

An international symposium on the fine-scale structure of the atmosphere and its relation to radio-wave propagation was held in Moscow in June 1965 under the auspices of the two international unions, URSI and IUGG, with about seventy participants. Sixteen papers on fluid dynamical aspects of irregular structure in the atmosphere and fifteen on radiophysical aspects are contained in this volume, some in English and some in Russian, with summaries in both languages in every case. The effect of a stable density gradient on the properties of turbulence naturally plays an important part in many of the papers.