REVIEWS

An Introduction to Fluid Mechanics and Heat Transfer, by J. M. KAY. Cambridge University Press, 1957. 309 pp. 37*s*. 6*d*. or $7.00.

The development of a satisfactory syllabus for students of engineering at the university is a difficult undertaking. Particularly is this true in the teaching of chemical engineers, the jacks-of-all-trades, or where the intention is to give a general engineering training without specialization. Professor Kay's book, which owes much to his experience of instructing chemical engineers at Cambridge University, clearly reveals the difficulties of compiling a course in one of the subjects that engineers study and the ingenious efforts which have gone towards overcoming these difficulties.

The problems that beset the university engineering instructor arise from a dilemma: must he make a choice between presenting an academic discipline and giving vocational training, or is a workable compromise possible? There is too much pressure from other subjects in the curriculum to allow full formal development of topics, nor would the mathematical equipment of the average engineering undergraduate permit it. Quite understandably, most student engineers are too eager to be applying their knowledge to be ready to spare much time and attention for the finer points. Kay definitely chooses to attempt the compromise. His book aims to be fundamental and systematic enough to provide some intellectual satisfaction, but the utility and possible applications of the analysis are emphasized at every stage in order to match the engineer's constructive outlook.

More than most, fluid dynamics is a difficult subject to teach to undergraduate engineers because only a limited amount of material can be taught with the aid of elementary mathematics of the standard also needed for the courses on mechanics, structures, thermodynamics and electricity, that the student is usually taking at the same time. This mathematical limit restricts the fluid dynamics course to what can be done by means of simple momentum statements, Bernoulli's equation and dimensional analysis, bolstered with empirical and theoretical facts taken on trust. That undergraduates' fluid dynamical training should often stop at this elementary level is very regrettable in view of the dominance of problems involving fluid motion in many current scientific and technological activities, as the pages of this journal show. Indeed, most newly graduated engineers would find the reading of this and kindred journals well beyond their immediate capacity.

Kay is evidently eager to remedy this situation, but naturally the transformation of undergraduate curricula cannot be achieved in one step. The result is what one might call a transitional book, where the author breaks from the customary limitations, but does not entirely find a satisfactory alternative. Vector notation must be adopted, the author decrees, and one applauds the decision, but still much of the essential matter is stowed away, half apologetically, in appendices. And if vectors are to be used, why should not elementary cartesian tensor notation also be introduced, particularly in the discussions of stress, strain and vorticity?

The separation of fluid mechanics from thermodynamics has become increasingly artificial and one may expect the appearance of more and more books which straddle the two subjects as this one does. As its title would suggest, the book contains only thermodynamical topics of relevance to fluid mechanics and heat transfer. The thermodynamic fundamentals are not well developed. One could wish for a stricter treatment of thermodynamical concepts and the abandonment of the term frictional heat where in fact no heat is flowing. The Second Law is neglected to a surprising degree. It is nowhere explicitly stated, although the significance of the sign of the entropy change in shocks is mentioned briefly. It is pleasing to find the parallelism between momentum, heat and mass transfer explained well, but there is need for a more forceful statement of the one-way nature of the interaction between the fluid motion and the heat transport in low-speed forced convection if the effect of temperature on fluid properties is negligible.

In view of Professor Kay's interest in the field of nuclear power, where fluid dynamics and heat transfer are closely inter-related, it is surprising to find so few references to nuclear engineering problems. To choose an instructive example, the inevitable concomitance of wall friction with heat transfer in pipe-flow is the dominant factor in the problem of cooling power reactors without excessive degradation of hard-won power in circulating the coolant. Heat transfer in high speed gas flow is another topic, important in many fields, which Kay's book neglects, while heat transfer at very low Prandtl numbers with liquid metals also receives scant attention.

The book is evidently based on a lecture course which occupied more than one year. One symptom of this is the way that topics such as the normal shock tend to reappear in more sophisticated detail as the book proceeds. Another is that facts are often asserted in the earlier chapters with references to proofs which appear in later chapters. This, though it weakens the logical structure of the book, is not a bad feature in what is obviously a textbook designed to buttress a parallel teaching programme. The first five chapters are devoted to elementary fluid dynamics, with illustrative examples. Two more specialized chapters on pipe flow and on pumps and compressors follow. For some reason turbines are discussed in an earlier chapter, amongst the miscellaneous applications of the basic ideas.

Kay next turns to heat transfer with brief treatments of conduction and heat exchangers. Dimensional analysis is taken up again and applied to heat transfer, and the co-existence of skin friction and heat transfer is discussed in another short chapter. The subsequent six chapters are rather strangely described in the preface as forming a hard core of basic theory. The significant word here presumably is ‘ hard ’, since more mathematical demands are now made on the student, with the development of the Navier–Stokes equations and simple applications thereof. There is a chapter on boundary layers, including the momentum equation, and another containing the usual superficial treatment of turbulent pipe flow. Successive chapters then turn to mass transfer, energy equations and again to forced convection. The book ends with five increasingly specialized chapters on compressible flow, open-channel flow, solid particles in suspension, packed beds and heat transfer with phase change. Being aimed at the necessarily versatile chemical or mechanical engineer, the book has to discuss cursorily a large number of topics. In consequence, some, particularly the later, chapters become a motley miscellany. The primary interest is in internal rather than external aerodynamics. Potential flow is mentioned only briefly, but a disproportionate amount of space is given to well-stated external boundary layer theory, both in the text and an appendix.

In comparison with most heat transfer textbooks, the book is refreshingly fundamental in outlook and refrains from too many unjustified assertions. The tenth chapter, in which dimensional analysis is applied to heat transfer, is particularly fair in developing this subject, notoriously suspect from an undergraduate viewpoint. The need for five basic dimensions in describing phenomena which do not involve the conversion of significant amounts of work or kinetic energy into heat and internal energy is well explained. On the other hand, to take an adverse example, the usual assertion that the Froude number is important when there is a free surface is not supported by clear and convincing arguments. Even in the last three highly specialized chapters the basic theoretical approach is preserved. In fact there is too little descriptive comment on the many formulae, and as a result justice is hardly done to the more empirical topics like heat transfer with boiling. Just occasionally the author turns to extensive practical details, notably at the beginning of the chapter on pumps and compressors.

Author and publishers are to be congratulated on producing a first edition so free from mistakes. Among the few errors is the unnecessary requirement that incompressible flow must be steady if the divergence of velocity is to vanish. Some reference to the idea of thermal ratio or effectiveness in heat exchangers seems desirable, and a clear definition of bulk or mixed temperature is necessary. There are many details which could be singled out as praiseworthy, such as the use of specific weight instead of density to make the hydraulicist's form of Bernoulli's equation dimensionally consistent. The collection of advanced examples which ends the book will be useful to university teachers. It is interesting to find Hartmann's analysis of the simple electromagnetic pump given as one of these examples.

Summing up, one may describe Kay's book as a useful textbook for general engineering undergraduate courses. For subsequent reference, engineers would do better to consult more advanced books with a more logical structure. Students of applied mathematics would also probably find such books more to their liking. Nevertheless, Kay's book has for its class an unusually fundamental outlook and, as remarked earlier, marks a beginning in the good work of persuading engineers to master vector analysis and other slightly advanced mathematical techniques.

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