J. Fluid Mech. (1983), vol. 127, pp. 562–567
Printed in Great Britain

REVIEWS

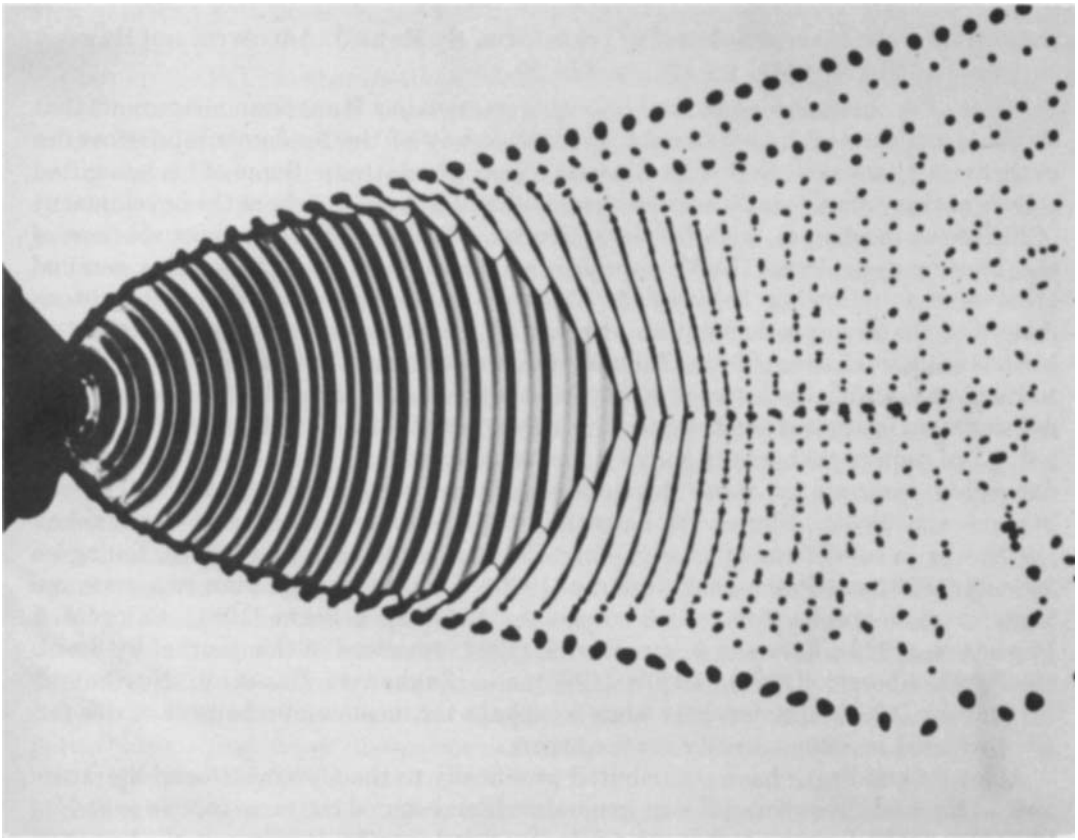
An Album of Fluid Motion. Assembled by MILTON VAN DYKE. Parabolic Press, 1982. 176 pp. $20 hardcover, $10 paperback.

I have been dipping into this fascinating collection of black-and-white photographs of fluid flow, taking one at a time the eleven sections into which the 280 photographs are grouped. It is not a book to be read for long stretches, because there is too much to think about as you study each photograph and test your understanding of each feature. I have not finished musing over the photographs, and doubt if I ever shall, since consultation on a specific point leads inevitably to browsing.

Professor Milton Van Dyke, well known for his contributions to theoretical fluid dynamics and now also as an enterprising do-it-yourself publisher, has had the bright idea of assembling and publishing photographs which show the nature of different representative flow fields. As he says in his introduction, 'Scattered through this century's literature of fluid mechanics is a treasure of beautiful and revealing photographs, which represent a valuable resource for our research and teaching'. With the advice and co-operation of colleagues round the world, he was able to locate and acquire many of the best photographs, and now that they have been reproduced in this album we can see just how beautiful and revealing they are. 'We' of course have always known how photogenic our subject is; now students and scientists in other disciplines will also be able to see.

Though these revelations of the flow patterns, some startlingly regular and smooth, some fantastically complex, are certain to intrigue the uninitiated, I think it is the professional fluid dynamicist who will benefit most from this book. Each photograph is an enticing challenge to one's comprehension of what is going on and an invitation to explain, to infer the conditions, and to conjecture on what would happen if... The photographs of supersonic flow are perhaps the most immediately educational, with their well-defined shock waves making strange but rational shapes and the amazing detail of shadowgraphs or interferograms. Devotees of low-Reynolds-number flow, boundary layers, vortices, hydrodynamic instability, turbulence, free convection, and free-surface flow will also find special sections of the book with much to ponder over. It was a joy for me to learn (from photograph 88) that when a semi-infinite cylinder is inclined to a uniform stream vortices are shed periodically with respect to distance from the nose so that the flow in a plane normal to the cylinder axis looks like a Kármán vortex street. The photographs have clearly been selected with great care and skill, and reproduced well on a large page ($21{\cdot}5 \times 28{\cdot}0$ cm) which allows details to be seen clearly. The photograph and caption shown here as an example have been reproduced directly from the book, with reduction in linear dimensions by a factor 0·8 to conform to a *JFM* page. In going through the book I accumulated only a few minor quibbles, one being that the families of dye-lines in two photographs of water flowing past aerofoils (numbers 23 and 34) could not have the alleged coincidence with streamlines, at any rate not accurately, since the spacing between adjacent dye-lines differs from what would be required for streamlines by conservation of mass.

There is a caption of several lines beneath each photograph to specify the conditions, to indicate the technique of visualization (of which there is an astonishing variety), and to interpret the picture briefly. But Professor Van Dyke avoids saying too much and the admirably concise captions do not give the reader more than the essential information (and, usefully, a reference in cases where the photograph has



149. Breakup of a liquid sheet. Studies of drop formation in sprays show that the production of filaments generally constitutes an intermediate stage. Controlled filament formation should therefore provide a means of regulating the size of drops. One approach is to subject the nozzle to forced vibrations. This photograph shows a flat laminar sheet of water issuing from a fan-spray nozzle that is oscillated axially at resonant frequency. *Photograph by N Dombrowski*

been published, as most of them have been, many in *JFM*). It is this feature, as well as the rather laboratory-oriented selection of photographs, that makes the book so appealing to university fluid dynamicists. Those who do not have the same passion to explain what they see and who simply revel in the wonders of the natural world might prefer a different selection – raindrops running down window-panes, drops of liquid hanging from a horizontal pipe, flames, dolphins swimming, birds flying, cilia, river meanders, cloud forms, desert sands, snow drifts, breaking waves on a beach, glaciers, etc. In most of these more natural subjects the fluid is transparent and the motion is made evident by its effects at the boundary of the fluid, so interpretation of photographs is less precise and more difficult. But I predict that Professor Van Dyke has given a decisive push to a movement that perhaps began with Prandtl, and that we shall be seeing more such collections of photographs which illuminate our subject. Meanwhile, all teachers of fluid mechanics should have a copy of this 'album' and should use it first to enlarge their own understanding and then that of their students.

G. K. BATCHELOR

Solitons and the Inverse Scattering Transform. By MARK J. ABLOWITZ and HARVEY SEGUR. SIAM, 1981. x+426 pp. $54.50.

Professor Feynman once remarked (in a conversation in a Hungarian restaurant) that he could understand how he might have made any of the fundamental discoveries in theoretical physics other than Einstein's general relativity. Some of his less-gifted colleagues may occasionally have entertained similar thoughts about the development of nonlinear mechanics, with Gardner, Greene, Kruskal & Miura's exact solution of the Korteweg–de Vries (KdV) equation as the singular exception. This seminal achievement, following Zabusky & Kruskal's numerical discovery that solitons dominate the asymptotic solution of the KdV equation and survive mutual interactions without change of form (Zabusky & Kruskal coined the term *soliton* to describe solitary waves with the latter property), initiated what is arguably the most exciting development in applied mathematics during the post-World-War-II era and generated a flood of papers that as yet shows no signs of subsiding. Until recently, however, connected accounts of these developments have been available only in survey papers – e.g. Scott, Chu & McLaughlin (1973), Miura (1976) and Makhankov (1978) – or in collections of articles – e.g. Flaschka & McLaughlin (1978), Lonngren & Scott (1978) and Bullough & Caudrey (1980). Now, within less than two years, we have six monographs from which to choose: Ablowitz & Segur (1981), Calogero & Degasperis (1982), Eckhaus & van Harten (1981; reviewed in this journal by Smith 1982), Eilenberger (1981), Lamb (1980) and Zahkarov, Manakov, Novikov & Pitayevsky (1980). I review here what is perhaps the most comprehensive of this set, after which I comment briefly on the others.

Ablowitz and Segur have contributed prolifically to the aforementioned literature and, along with Newell and Kaup, generalized (and coined the term *inverse scattering transform* (IST) for) the technique originally developed by Gardner *et al.*, Lax, and Zakharov & Shabat. They are, and write as and for, applied mathematicians, and both the strengths and the weaknesses of the present book derive from this fact. Their style is casual (with phrases such as 'lurking in the background' and 'lousy approximation'), and typos are not infrequent (although I did not notice any serious errors). The almost complete absence of physics from the first 80% of the book is perhaps unfortunate from the viewpoint of the student, but it presumably affords an efficient development. (I was reminded, in reading the first three chapters in the present book, of Titchmarsh's statement, in the Preface to his *Theory of Fourier Integrals*, that 'I have retained, as having a certain picturesqueness, some references to "heat", "radiation", and so forth; but the interest is purely analytical, and the reader need not know whether such things exist'.)

Chapter 1, 'The inverse scattering transform on the infinite interval', opens with a review of the nineteenth-century work of Russell, Boussinesq, Rayleigh and Korteweg & de Vries on solitary waves, and of the recent work of Fermi, Pasta & Ulam, Kruskal & Zabusky, Gardner *et al.*, Lax, Zakharov & Shabat, and Ablowitz, Kaup, Newell & Segur on solitons and inverse scattering theory. The basic theory for the solution of nonlinear evolution equations of appropriate form then is developed using the Lax–Zakharov & Shabat formalism as generalized by Ablowitz *et al.* The results, due originally to Gardner and Zakharov & Fedeev, that the equations solvable by IST are completely integrable Hamiltonian systems and that 'IST amounts to a canonical transformation from physical variables to (an infinite set of) action-angle variables' are developed in some detail. The chapter ends with an extensive discussion of the asymptotic behaviour of solutions for initial conditions that generate no solitons, based largely (and appropriately) on the original work of the authors.

Chapter 2, 'IST in other settings', deals with the three-wave interaction problem, two-dimensional (two space dimensions plus time) equations, discrete problems such as the Toda lattice, and the KdV equation with periodic boundary conditions. This last problem is of special interest in that numerical solutions for the infinite interval typically posit periodic boundary conditions with a wavelength that is large compared with the characteristic length of the phenomena under consideration; however, numerical techniques are not discussed in the present monograph (although numerical results are presented).

Chapter 3, 'Other perspectives', opens with an overview of the intrinsic characteristics of IST problems and of the question (still open) of determining whether or not IST is applicable to a given problem. Bäcklund transformations and Wahlquist & Estabrook's closely related method of 'pseudopotentials', including the basics of Lie algebras, are developed at length. Direct methods for finding soliton solutions are presented, following the original work of Hirota. Rational solutions of nonlinear evolution equations, such as the 'lump' solution of the Kadomtsev–Petviashvili equation, are discussed. Kruskal's method of examining solitons in terms of pole interactions in a complex plane is developed. There is an extended discussion of Painlevé transcendents and the 'Painlevé conjecture' of Ablowitz, Ramani & Segur that 'A nonlinear PDE is solvable by an inverse scattering transform only if every nonlinear ODE obtained by exact reduction is of P[Painlevé]-type, perhaps after a transformation of variables'. The chapter closes with an extended discussion of perturbations (e.g. weak dissipation) of integrable evolution equations and of the transverse stability of solitons.

Chapter 4, 'Applications', deals with 'completely integrable equations as models of physical phenomena.' The authors' viewpoint is perhaps manifested by their statement that 'the most common physical meaning of the nonlinear evolution equations that we have been studying [is that] they are the consequence of suppressing secular terms in a formally asymptotic expansion'. They emphasize that, although the evolution equations under consideration are fully nonlinear, they represent small deviations from some basic equilibrium state (e.g. the KdV equation governs the slow change of a wave through weak dispersion and weak nonlinearity in a reference frame moving with the intrinsic wave speed). They also emphasize that 'What one gains ordinarily by solving these nonlinear evolution equations is not primarily the ability to discuss large deviations from the equilibrium state, but rather the ability to discuss relatively small deviations over a long time scale'.

Under the rubric 'KdV equations and their cousins', there is a detailed derivation of the KdV equation, an illuminating exposition of the experimental support for the theoretical predictions from that equation, a brief but adequate discussion of internal solitary waves based on a two-layer model, and a still briefer discussion of Rossby-wave solitons and Maxworthy & Redekopp's conjecture that Jupiter's Great Red Spot may be such a soliton. (Fashions change: Raymond Hide, in a jesting reference to a now-discarded theory, once defined a Taylor column as that phenomenon which is responsible for the Great Red Spot.) There follow discussions of resonant interactions in nonlinear optics and among both internal and surface gravity waves, of the sine–Gordon equation and self-induced transparency, and of IST in general relativity and quantum field theory.

The appendix contains a review of the Fourier-integral approach to linear evolution problems with particular emphasis on the dispersion relation between the spectral variables of frequency and wavenumber and on asymptotic evolution for large time. Each chapter is followed by a set of exercises, which range in difficulty from filling in missing steps in the text to problems for which the solutions remain open.

It remains to compare Ablowitz & Segur with the previously cited monographs. Eckhaus & van Harten (1981) aim at a 'mathematically rigorous and satisfactory' presentation, write in a theorem–corollary–lemma format, and eschew physics. Lamb (1980) aims at 'an elementary introduction' for students in applied mathematics or physics; he assumes only that the reader has a background in the physical sciences, develops one-dimensional scattering theory, both direct and inverse, *ab initio*, and includes well selected exercises. Eilenberger (1981) writes for graduate students in theoretical physics, but his exposition is more compact and at a higher mathematical level than that of Lamb, and he does not include exercises. I have been unable to obtain a copy of Zakharov, Manakov, Novikov & Pitayevsky (1980) (which, in any event, is in Russian); however, the authors' published papers suggest that their monograph might be inspiring for the mature research worker but rather intimidating for students. [Calogero & Degasperis (1982) had been announced by the publishers but was not available as of September 1982.] Ablowitz & Segur write at a more sophisticated (applied) mathematical level than either Lamb or Eilenberger and go into much more complicated problems. Their wealth of detailed information should prove valuable for the research worker, but, despite the provision of exercises, I expect that their monograph would be suitable as a text only for a rather specially selected group of students. On balance, I recommend Lamb as a text for a graduate course and Ablowitz & Segur for research workers in fluid mechanics; any well stocked library should have both.

JOHN W. MILES

REFERENCES

BULLOUGH, R. K. & CAUDREY, P. J. (eds) 1980 *Solitons*. Topics in Current Physics, vol. 17. Springer.

CALOGERO, F. & DEGASPERIS, A. 1982 *Spectral Transforms and Solitons: Tools to Solve and Investigate Nonlinear Evolution Equations*. Studies in Mathematics and Applications, vol. 13. North-Holland (announced by publisher but not available as of September 1982).

ECKHAUS, W. & VAN HARTEN, A. 1981 *The Inverse Scattering Transformation and the Theory of Solitons*. North-Holland.

EILENBERGER, G. 1981 *Solitons: Mathematical Methods for Physicists*. Springer.

FLASCHKA, H. & MCLAUGHLIN, D. W. (eds) 1978 Papers presented at a Conference on the Theory and Application of Solitons (Tucson, 1976). *Rocky Mountain J. Math.* **8**, 1–428.

LAMB, JR., G. L. 1980 *Elements of Soliton Theory*. Wiley.

LONNGREN, K. & SCOTT, A. (eds) 1978 *Solitons in Action*. Academic.

MAKHANKOV, V. G. 1978 Dynamics of classical solitons (in non-integrable systems). *Phys. Rep.* **35**, 1–128.

MIURA, R. M. 1976 The Korteweg–de Vries equation: a survey of results. *SIAM Rev.* **18**, 412–459.

SCOTT, A. C., CHU, F. Y. F. & MCLAUGHLIN, D. W. 1973 The soliton: a new concept in applied science. *Proc. IEEE* **61**, 1443–1483.

ZHAKHAROV, V. E., MANAKOV, S. V., NOVIKOV, S. P. & PITAYEVSKY, L. P. 1980 *Theory of Solitons. The Method of the Inverse Scattering Problem* (in Russian). Nauka (cited by Ablowitz & Segur).

Nuclear Energy Technology, Theory and Practice of Commercial Nuclear Power. By RONALD A. KNIEF. Hemisphere/McGraw-Hill, 1981. 600 pp. $33.95.

Decay Heat Removal and Natural Convection in Fast Breeder Reactors. Edited by A. K. AGRAWAL and J. G. GUPPY. Hemisphere/McGraw-Hill, 1981. 423 pp. $55.

Nuclear Reactor Safety Heat Transfer. Edited by O. C. JONES. Hemisphere/McGraw-Hill, 1981. 959 pp. $99.

The first of these three volumes is by an author whose present responsibilities, Manager of Training Facilities at Three Mile Island for the General Public Utilities (an appointment taken up after the TMI-II accident) make this study text on the practice of nuclear power particularly interesting. It has a broad coverage, directed mainly at nuclear power reactors themselves rather than the associated infrastructure of enrichment, waste management, etc., although these aspects are not ignored. The text is far more than a reactor-physics, reactor-engineering text, and includes a chapter on possible fusion reactors and aspects of public concern, acceptability, etc., including problems of proliferation and safeguards. It makes relatively light demands on mathematical ability and would be suitable therefore for training of operators as well as an undergraduate text, albeit with an entirely US approach.

The second volume is the record of the Brookhaven Specialists' Meeting devoted to thermal safety in the fast breeder reactor. A wide range of international review and application papers are included in a well-presented record. Major divisions of papers are: Out-of-pile Experiments; Analytic Modelling; Experiments and Analyses. A section discusses problems in gas-cooled fast reactors, but naturally enough the major portion of the effort was directed to sodium cooling. The proceedings provide a valuable review of the state of safety research in the area with the one omission of the concern that a liquid-metal coolant might provide for a self-induced magnetodynamic generator and the possibility of an electrical back-pumping negating the coolant circulation.

The third volume is a substantial textbook directed to safety consideration in the cooling of nuclear power reactors, both light-water and liquid-metal cooled. It resulted from the 1980 Summer School at Dubrovnik (International Centre for Heat and Mass Transfer). It contains much advanced material but no problems and therefore will be more suitable as a reference book or for collateral reading than as a primary text even in a graduate course. The book gives a good understanding of design base accidents for both reactor types and a specialist study of the Three Mile Island accident (1979).

J. D. LEWINS

CORRIGENDUM

The premixed flame in uniform straining flow

By P. A. DURBIN

Journal of Fluid Mechanics, vol. 121, 1982, pp. 141–161

The stability analysis in §3 contains an error. As given it is valid for two-dimensional disturbances, for which $l = 0$. For three-dimensional disturbances it is correct only in the limits of short and long wavelength. Because of the latter, it can still be concluded that straining acts to suppress the longwave instability.