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# REVIEWS

**Frontiers in Fluid Mechanics.** Edited by S. H. DAVIS and J. L. LUMLEY. Springer-Verlag, 1985. 287 pp. DM 90.00.

Stanley Corrsin died on 2 June 1986. This volume, dedicated to him, records the contributions to a symposium attended by him, his colleagues, students and friends that was held in Evanston, Illinois early in 1985 to celebrate his 65th birthday. It was a happy event, there being then no shadow of the illness that was ultimately to overwhelm him. In the circumstances I am using this review as an opportunity to pay tribute to a distinguished fluid dynamicist.

He was born on 3 April 1920 in Philadelphia and received his Bachelor's Degree in Mechanical Engineering from the University of Pennsylvania at the age of twenty. Having developed an interest in aerodynamics, he went to the California Institute of Technology to work with von Kármán and Liepmann in the Gugenheim Laboratory. He was the latter's first advisee, receiving his MS in aeronautics in 1942 and Ph.D. in 1947. At about this time, Francis Clauser was establishing the Department of Aeronautics at The Johns Hopkins University and he recognized early Stan's potential ability to play an influential role in the development of our knowledge about turbulence. Already, Corrsin had shown great intellectual and experimental skills and Clauser had no hesitation in offering him a faculty position in the new department. Kovasznay had recently arrived from Hungary. Corrsin accepted; the nucleus had formed of one of the most productive experimental groups in turbulence research. Stan remained at Hopkins for the rest of his career, ultimately being named the Theophilus Halley Smoot Professor of Fluid Mechanics. He was a member of the National Academy of Engineering, Docteur Honorio Causa of the University of Lyon and Fellow of the American Academy of Arts and Sciences, the American Physical Society and American Society of Mechanical Engineers.

Stan never cared too much for travel or for academic administration, though he was inevitably obliged to do both. His sabbatical leaves were spent generally in Baltimore and offered not a change of scene, but a chance to concentrate exclusively on research. He did travel to France and to his favourite Fluid Dynamics meetings of the American Physical Society, but he did not need the stimulus of varied academic environments – he made his own, attracting many students and post-doctoral fellows who have subsequently become international figures themselves. Administrative responsibilities were thrust upon him. In 1955 he became Chairman of the Mechanical Engineering Department at Hopkins and set about the task of building active research groups in both solid and fluid mechanics, but when in 1960 this department amalgamated with Civil Engineering and his old department, Aeronautics, he happily relinquished the chairmanship to George Benton. He did it totally, even having a rubber stamp made reading 'Let George do it' which he used freely on university documents before sending them on. Nevertheless, his vision, his intelligence, his thoroughness and his dedication to the highest standards of academic integrity inspired the Mechanics Department in its flowering during the 1960s. Though never a pedant, he was impatient with sloppy reasoning or unstated assumptions, insisting that advances in understanding required the asking of fundamental questions, not the development of 'engineering approximations'. For him, G. I. Taylor was the epitome of an engineering scientist; his own work embodied the same characteristics of revealing experiment, directed towards the development of a clear insight into a problem reduced to its essentials. Science begins, he would say, by asking simple questions about complex phenomena but advances by asking more penetrating questions about simpler systems, whose solution could be obtained with rigour and explained with clarity. If an unwary colleague commented that some question was academic, his inevitable response was, 'This is an academic institution, where we consider academic questions'. If an unwary dean or senior colleague acted pompously, he would be gently but firmly deflated; if he acted from expediency, he would be reminded of the principles that had to be observed or the standards that had to be maintained.

Yet Stan was always helpful and supportive of his students and junior colleagues who treasured his lasting friendship. The 10 am coffee hours beside the fan of his big wind tunnel were a tradition where colleagues and students would gather to read Punch, talk noisily about science and everything else, enjoy Stan's wry humour and, incidentally, to drink coffee. Regulars who visited other universities were expected to bring back a local coffee mug, and the collection expanded as the years went by. Occasionally on Fridays there was a wine and cheese party to honour a visitor or a new Ph.D. or simply because it was the end of the semester. All were welcome – faculty, staff, undergraduates, graduate students and post-docs.

Of course, Stan regularly taught turbulence at Hopkins, and during the last few years he developed an undergraduate course 'Dynamics of Animal Motion' (including a laboratory) which bemused a generation of pre-meds. His examination problems were usually open-ended. One take-home question in his basic fluid-mechanics course gave a quotation from *The Joy of Cooking* for poaching an egg: 'Swirl the water into a mad vortex with a wooden spoon. Drop the egg into the well formed at the center of the pot. The swirling water should round the egg', and asked the student to explain. Clearly an invitation to experiment and think, rather than to calculate blindly!

Corrsin's own researches and those in collaboration with his students brought him distinction in the field of turbulence and turbulent transport, but his interests ranged into biomechanics and statistical geometry. One of his first notable contributions was his realization in 1943 that in unconfined turbulent flows such as wakes or jets, the convolution of the free turbulent boundary was a reflection of the energetic eddies inside and as the flow sweeps past a fixed observation point, the turbulence at that point is intermittent, with regions of vortical flow in billows alternating with non-turbulent but perhaps still fluctuating regions of irrotational motion. Later, in 1954 with Kistler, he showed that the thickness of the transition region between the turbulent and irrotational motions is very thin, proportional to the Kolmogorov microscale, and that the turbulence encroaches on the outer fluid at a speed proportional to the Kolmogorov velocity scale, while at the same time, the interface is continually convoluted on a larger scale by the more energetic eddies of the flow. These conclusions have certainly stood the test of passing time; it is still very difficult to improve upon them. Later work by Kovasznay and others using the same technique of conditional sampling has led to the identification (and occasional mis-identification) of coherent structures in turbulent flows, still a fashionable area of research. In 1948–49, Alan Townsend, working in Cambridge and Stanley Corrsin at Hopkins independently found experimental evidence of local isotropy in turbulent shear flows, a cornerstone of Kolmogorov's theory of local similarity. He continued throughout his career to devise experiments that would expand our understanding rather than simply provide additional data. His study in 1980 with Kellogg on the evolution of a spectrally local imposed perturbation upon isotropic turbulence examined Kraichnan's idea of a spectral response tensor in the first of the new generation of turbulence spectral theories. It was natural that Stan's interests would not be confined to turbulence dynamics and the natural extension to turbulent mixing led to his discovery in 1951 of the $(-\frac{5}{3})$ law for the spectrum of temperature fluctuations in isotropic turbulence. Though he did not elaborate on the point, he recognized clearly the differences that must exist at the high-wavenumber end of the spectrum for large and small Prandtl numbers, a matter that was clarified by Batchelor and his colleagues in 1959.

The relationship between the Eulerian and Lagrangian specifications of turbulent flow was a recurrent interest. His very neat demonstration in 1952 that the turbulent diffusivity in a uniform temperature gradient could be expressed in terms of the Lagrangian integral timescale has become a classroom classic. He and Karweit measured the growth in length of material lines in turbulent flow in 1969, and in 1972 he gave a simple proof of the conjecture, long held, that such lines will on average lengthen. He had already been fascinated by the statistical-geometrical questions suggested by the randomness of tubulence – given an indefinitely large region containing random surfaces homogeneously located in the mean, what is the relationship between the average area of surface per unit volume and the average number of cuts per unit length made by a sampling line? (1955). What is the average contour length per unit axis length of a multiply-valued stationary random function in terms of the average number of intersections of sampling lines? (1961)

In the 1970s, his attention was drawn to biological fluid mechanics, and again his good taste led him to questions that were important, simple and illuminating. With Berger, he studied *in vivo* the process of advance of the precorneal tear film towards the upper eye-lid after a blink and developed a quantitative theory based on the surface-tension gradient in the film. Several contributions on placental blood flow with Davis and Erian modelled the 'villous tree' containing the fetal capillaries as a deformable porous medium with a local permeability increasing with increasing local flow speed.

The book under review reflects mainly Corrsin's interests in turbulence, but also includes the work of his former students, colleagues and friends in other branches of fluid mechanics. Two chapters describe experimental studies on transition. Sreenivasan's measurements in the wake of a circular cylinder are interpreted in terms of low-dimensional chaos while those of Riley and Gad-el-Hak on the dynamics of turbulent spots, eschewing philosphy, concentrate on beautiful flow visualizations with ensemble averaging to characterize the internal structure. The dynamics of homogeneous turbulence is of course represented. Le Penven, Gence and Comte-Bellot describe recent experiments on the old problem of the approach to isotropy in homogeneous turbulence, Herring reviews two-point closure methods in both three-dimensional turbulence and two-dimensional random flows, and O'Brien discusses the spectra of reactants in homogeneous turbulence. The questions of intermittency and conditional sampling are examined by Kollmann with applications to combustion, M. M. Gibson describes measurements and modelling of the effect of streamline curvature on turbulence, and Lumley and Van Cruyningen point out the limitations of second-order modelling of passive scalar diffusion, concentrating on the dispersal from a line heat source in a turbulent flow. Marguiles and Schwarz consider acoustic wave propagation in a variety of fluids, Newtonian, visco-elastic and mixtures with coupled reactions. Finally, Rosenblat and Davis ask 'How do liquids spread on solids?' and explore the influence of moving contact lines on the evolution of drops of both Newtonian and visco-elastic liquids. At the beginning of the volume, there is a good photograph of Stan, and at the end a complete list of his publications.

As a tribute to Stan from some of his friends, the book is of course incomplete, but the fact that so many of the contributions have their roots in either Corrsin's own research or the standards of experimental excellence he imparted to his students gives some measure of the influence he had. Viewed simply as a collection of essays, it certainly provides a valuable summary of a number of areas of active research in fluid mechanics. To his old friends and the admirers of his work, it is much more.

O. M. PHILLIPS

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**Introduction to Water waves.** By G. D. CRAPPER. Ellis Horwood, 1984. 224 pp. £22.50.

The author's aim 'is to present the basic theory of water waves in a straightforward way using direct rather than sophisticated mathematical techniques'. Presumably this bias against advanced mathematics is to make the subject-matter available to a wide audience. The book looks attractive with a good sprinkling of diagrams and plenty of photographs.

In the first chapter the reader is rapidly introduced to equations of motion, an energy equation, boundary conditions and approximations. Chapter 2 introduces periodic wavetrains with the linearized solution for gravity-capillary waves, followed by a brief treatment of Stokes waves and Crapper's finite-amplitude capillary-wave solutions. Towards the end of this chapter the main thrust of the book is revealed with a relatively full account of group velocity and rays including the effect of currents which lead to rays not being orthogonal to wave crests. In subsequent chapters energy, momentum, wave action and wave-induced depth variations are introduced. Applications include waves approaching beaches, radially spreading waves, and ship waves.

Chapter 6 gives further linear-wave examples, a wavemaker, diffraction, waves on a thin sheet and waves on an internal interface. The final chapter treats nonlinear shallow-water examples; introducing simple waves, hydraulic jumps, bores, solitary and cnoidal waves. Each chapter concludes with a set of problems. Full solutions are given at the end of the book for the more difficult problems.

The main text only occupies 187 pages, so many topics are treated quite briefly. This is satisfactory in many examples in this 'introduction', especially as references are given for further reading, including journal papers. However, there are a number of places where a little more explanation would be a great help. It might have been noted that assuming periodicity of the water velocity due to waves is not universal. The alternative natural choice of imposing zero mass flux on the wave motion is often used and much confusion results.

Despite the author's warning that some introductory knowledge of fluid mechanics is desirable I am disappointed that no attempt is made to justify the assumption of irrotational flow. There are other points where a few careful words about the validity of approximations could be useful; for example, despite some comments on reflection, the ray-theory result, in equation (5.38), that wave amplitude approaches infinity near a caustic is interpreted as wave breaking, as is wave focusing on page 140.

The most advanced mathematics used is complex-variable theory including conformal mapping for Longuet-Higgins's neat approximation to steepest waves. Otherwise, practice may be needed to follow the interchange of integrals and partial derivatives in deriving averaged equations. Some more advanced results such as a diffraction solution are just quoted

The typography is good, and only one misprint was noted; but in a few places the author's choice of words is too familiar for my taste. One bloomer does upset me. I frequently use phase velocity as an example of a quantity which has magnitude and direction and is *not* a vector (e.g. try adding phase velocities, or note that a component is best defined as $c/\cos\theta$ rather than $c\cos\theta$), yet a 'vector phase speed' is introduced on page 52.

My overall assessment is that despite some slight blemishes *An Introduction to Water Waves* is an attractive book which could prove useful for those who need to learn about water waves and interesting for those who wish to learn about them.

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