Sir James Lighthill: In remembrance

It was with a sense of disbelief that I heard my wife read out, on the morning of 20 July, the news that Prof. James Lighthill had died three days earlier in a swimming accident. A thought flashed through my mind – it cannot be, no more thrilling papers from the master craftsman. Lighthill was a peerless applied mathematician and fluid dynamicist, one of the greatest of this century; of whom Sydney Goldstein, I believe, said that whatever he touched he turned to gold. His giant strides over a half a century spanned the fields of aeronautics, applied mathematics, astrophysics, atmospheric and oceanographic sciences and biofluid dynamics. The news report suggested that he had died as he had lived: undertaking the challenge, at the age of 74, to swim, in rough English channel seas, the 15 km around the island of Sark that he had first successfully undertaken 25 years earlier. This was, unfortunately, one of the very few challenges that he had failed to surmount; even the greatest amongst us are, after all, mortal.

Born on 23 January 1924, Michael James Lighthill had his undergraduate education at Trinity College, Cambridge, during the war years 1941–43. He published his first paper, on supersonic aerofoil theory, a few days before his 20th birthday. Some milestones of his meteoric career: Beyer Professor at Manchester in 1950, Director, Royal Aircraft Establishment in 1959, Royal Society (RS) Research Professor, Imperial College in 1964, Physical Secretary, RS, in 1965, Lucasian Professor of Mathematics, succeeding Dirac, at Cambridge in 1969, and Provost, University College London in 1979, the university he had been associated with till his death. He received all the honours that naturally come to a man of his stature: Fellowship at Trinity, Fellowship of the RS, various medals of the RS, memberships of many foreign academies, honorary doctorates, memberships of the editorial boards of many journals, etc. He was knighted as Sir James Lighthill in 1971.

A problem that one faces when one wants to briefly outline the work of a scientist as prolific as Lighthill is, what does one select since there is such an embarrassment of riches? On the positive side, since all the work is of such high quality, one can select anything. So I shall just outline a few contributions chosen mainly to display the amazing width of his expertise.

His early work, influenced by the needs of the war and early post-war years, was in the general area of high speed aerodynamics. Among his many sparkling gems, let me mention only two, his contributions to the hodograph method for transonic flows and his invention with G. B. Whitham of the method of strained coordinates. In the former, a notoriously difficult nonlinear problem is, by going to the hodograph plane, reduced to a linear problem; the price paid, however, is that now the

boundary conditions are unpleasant, there are singularities in the field and the relevant functions are multivalued. The ingenious method devised by Lighthill to overcome these hurdles and to handle solid boundaries was fully exploited for design purposes only many years later, when powerful computers became available. When an aircraft flies at supersonic speed, it overtakes the disturbances it generates and these pile up behind it as an approximately conical sonic boom. Whitham and Lighthill showed that, although the magnitudes of the disturbances were correctly given by linear acoustic theory, the characteristics along which the disturbances propagate were not and had to be correctly accounted for in the nonlinear theory. This they achieved using the method of strained coordinates (also known as the PLK method), a technique they invented. Lighthill successfully applied this method, normally applicable only to hyperbolic wave problems, to a variety of other problems.

In the fifties and sixties, one of the most serious problems facing aircraft jet engine manufacturers was the problem of jet noise. The noise from a highly turbulent jet is caused by the turbulent fluctuations in the jet. How could this be estimated when so little was known about turbulence itself? In a pair of papers of great insight, Lighthill showed, by a skilful recasting of the governing equations and making a number of reasonable assumptions about the nature of the turbulent field in the jet, that the noise from a subsonic jet increases in proportion to the 8th power of the jet Mach number. This is the celebrated 'Lighthill's 8th power law'. I should add that whereas MJL left the area after writing the seminal papers, a legion of less well-endowed colleagues made their bread and butter for years out of the area that had been opened up by him.

In the sixties and the seventies Lighthill, working closely with physiologists and biologists, made many fundamental contributions to biofluid dynamics. These include his work on animal locomotion in general and the swimming of fish in particular and on the flow of energy in the cochlea. My own favourite is his elegant work on the Weiss–Fogh mechanism of lift generation. The Cambridge zoologist Weiss-Fogh had made in 1973 the remarkable discovery that the wasp *Encarsia formosa* generated unusually high lift coefficients by a non-classical mechanism. Lighthill analysed this lift mechanism using an inviscid, two-dimensional model and showed exactly how the lift was generated. A fruitful interaction between a biologist and a mathematician.

As a final example of Lighthill's work let me just mention his analysis of a device designed and manufactured by Vickers Ltd to generate energy from the ocean. Their basic idea was to use submerged resonant ducts, nice robust devices, to extract the energy from the pressure head associated with the more regular ocean swell rather than from the more variable waves. Lighthill was able to cleverly model the device and process and, as in so much of his other work, use complex analysis to pull out the relevant answers.

Like many other great scientists, his success was due to his uncanny ability to take a difficult, messy problem, distil out the essence and then sort this out rapidly and skilfully. Apart from his great physical intuition, he combined in himself a mastery of classical mathematical analysis with a remarkable capacity to carry out difficult calculations rapidly and effortlessly. He was also an excellent speaker who could hold his audiences spellbound with his erudition, enthusiasm and wit; he was greatly in demand at conferences.

For us in India, there was something special about Sir James Lighthill because, I believe, he had a soft corner for India and Indian science. He has graciously written the preface for a number of books written by Indian scientists. I have always had the impression that he was especially generous in making helpful suggestions, in providing encouragement, and even in the matter of acceptance when he acted as editor for a journal; I have to ruefully admit that I have, myself, been a beneficiary of such generosity. But it has not all been one way. His collected papers have been edited by M. Y. Hussaini, now settled abroad but originally from Chennai, who was an advisee there of Prof. Abdurahiman, who was himself an early student of Lighthill at Manchester! Lighthill had visited India on a number of occasions. He first came in 1961 to give an invited talk at a conference organized in Bangalore by Dr. P. Nilakantan, the first Director of NAL. His visit in 1989 was in connection with the Golden Jubilee of CSIR; he had been invited to give talks at a number of venues around the country. All of us who met him at the time were charmed not just by his scientific talks but also by his modesty and graciousness.

Yes, he will indeed be missed. We can no longer look forward to those fascinating papers; we shall have to be content to be inspired and guided by the monumental work that he has left behind. In contemplating the sad manner of his passing away, we can take solace in the fact that at least he was surrounded by those things that fascinated and delighted him – the water, the waves and the fishes.

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Synthesis of meteorological observations and modelling studies to assess climate change mitigation strategies over India

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[*Curr. Sci.*, 1998, **75**, 95–97]

1. References 6, 11 and 14 should read as follows:
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2. The authors' affliation at the bottom should read: *H. N. Srivastava is in the Indian Meteorological Department, New Delhi 110 008, India. Malti Goel is in the Department of Science and Technology, Ministry of Science and Technology, New Mehrauli Road, New Delhi 110 016, India.*

Air pollution in Calcutta during winter – A three-year study

Gautam Samanta, Gautam Chattopadhyay, Badal K. Mandal, Tarit Roy Chowdhury, Partha P. Chowdhury, Chitta R. Chanda, Prabal Banerjee, Dilip Lodh, Dipankar Das and Dipankar Chakraborti

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The heading of column 4 of Table 10 should read, Pb ($\mu g/m^3$) and not Pb (ng/m^3) as printed. The error is regretted.

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