OBITUARY NOTICES

LORD RAYLEIGH.

John William Strutt, afterwards Baron Rayleigh, was born on November 12th, 1842. His early education was mainly at a private school. He entered as a Fellow Commoner at Cambridge in 1861, read mathematics with Routh, and, after a brilliant undergraduate career, graduated as Senior Wrangler in 1865. He was shortly afterwards elected to a Fellowship of his College (Trinity). He succeeded to the peerage in 1873.

Within a few years of his degree he began that career of original scientific investigation which continued without intermission almost to the day of his death, and was ultimately to establish his fame, after the departure of his great compeers Stokes, Kelvin, and Maxwell, as the supreme authority in physical science. It is unnecessary here to attempt a record of the manifold distinctions which were conferred on him or the important offices to which he was called. One or two matters may however be mentioned. In response to a pressing invitation he accepted the Cavendish Professorship of Physics in 1879, in succession to Maxwell; this he held till 1884. He was Secretary of the Royal Society from 1885 to 1896, and President from 1905 to 1908. His long and intimate connection with our own Society dates from 1871. He was President in the years 1876–7, and received the De Morgan medal in 1890. It is a matter of some pride to recall that much of his earlier and most characteristic work on Sound and Vibrations made its first appearance in our *Proceedings*. Nor should we forget his solicitude for the welfare of the Society, and the generous contribution which he made to its funds, at a time of financial stress.

Rayleigh's closest affinities were to the great dynamical school of which the three great physicists already named were exponents. In respect of the massive solidity of his work, and serene breadth of judgment, he stands nearest perhaps to Stokes, for whom indeed he had an intense admiration. This found eloquent expression in the obituary notice which he wrote for the Royal Society. One sentence, among others, may be picked out from this memoir as equally applicable to himself: " Instinct amounting to genius and accuracy of workmanship are everywhere manifest; and in scarcely a single instance can it be said that he has failed to lead in the right direction."

A survey of his achievements from the physical point of view must be sought elsewhere.* In these pages some account may be looked for of his characteristics as a mathematician. It must be recognised that his main interest was in the unravelling of physical phenomena, and that mathematics was to him chiefly valuable as an auxiliary. Moreover, just as in his experimental work he had recourse by preference to the simplest devices, so the mathematical apparatus, whenever possible, was of the most elementary character. There was always, however, enormous mathematical power in reserve, and whenever the occasion called for it the utmost degree of skill of this kind was brought to bear. One striking instance among others was his application of Hill's highly original methods in the Lunar Theory to the optics of stratified media. But perhaps the most original feature in his own mathematical work was the development of approximate methods, by which problems utterly refractory (in their rigorous form) to analysis receive a solution fully adequate for practical purposes. An early instance is the treatment of the Helmholtz resonator as a system of one degree of freedom. The treatise on *Sound* contains many other examples.

His earliest papers relate chiefly to Sound and Optics. The book on *Sound* just referred to is remarkable for the great development given to the theory of Vibrations. This theory, originated by Bernoulli and Lagrange, and further elucidated by Thomson and Tait, was greatly extended by him, and runs as a leading thread through the whole book. The work as a whole ranks as a classical achievement, and has entirely transformed the subject. Many of the theorems which it contains have applications not only in other branches of mechanics but in such subjects as Electricity and Heat.

In Optics he proceeded at first on the basis of the old elastic theory of the æther, until he became convinced that it was untenable, or rather as he expressed it, " too wide for the facts." His later work was in terms of the electromagnetic theory, although many investigations are independent of the particular hypothesis adopted. One of the earliest problems which he took up was the scattering of light by small particles. To this he returned more than once, with the final conclusion that the scattering by the molecules of the air, apart from the influence of grosser particles,

* See the memoir by Sir Arthur Schuster, *Proc. Roy. Soc.*, (A), Vol. 98.

would account for the blue of the sky. Other investigations were on the theory of gratings, which he simplified, and on the resolving powers of spectroscopes, and of optical instruments in general. This theory is in fact largely of his creation. As an instance of his power in putting old matters in a new light and dispelling obscurities we may cite his elucidation of "Huyghens' principle," which had long been a perplexity to serious students of the subject. By great good fortune he was induced to write a connected account of the theory of Light, as he regarded it, in the form of two articles contributed to the *Encyclopædia Britannica*. These are included of course in his collected papers, but might well be published separately. They constitute by far the best textbook on the subject which has ever appeared.

From the theory of Sound and Vibrations to Hydrodynamics, especially in relation to problems of small oscillation about a state of equilibrium or of steady motion, was a natural transition. His first paper on the subject deals with water waves, and reproduces the fundamental results of Airy, Stokes, and others, by an elegant and simplified analysis. The "solitary wave" of Scott Russell was also elucidated, and it was explained in particular why such a wave must necessarily be one of elevation only. Rayleigh was scrupulous here, as in all similar cases, to point out where he had been anticipated. Boussinesq in this instance shares the credit of clearing up a matter which had long been obscure. The theory of deep-water waves of permanent type, which had been the subject of a classical research by Stokes, had a lasting fascination for Rayleigh, who returned to it again and again, continually improving the approximations. The influence of capillarity on water-waves had been considered by Kelvin in 1871. The subject was taken up and completed by Rayleigh, who investigated the train of waves and ripples set up by a travelling disturbance. The paper referred to, which appeared in Vol. IX of our own *Proceedings*, is remarkable for a characteristic analytical artifice which subsequent writers have found very useful. A mathematical indeterminateness which presents itself in various problems of steady motion (owing to the implicit inclusion of free waves of a certain period), when dissipation is neglected, is evaded by the temporary introduction of frictional forces varying as the velocity, whose coefficient is ultimately made to vanish. The result must be the same as if the true law of viscosity had been employed, but the analysis is much simpler. In this connection we may recall the beautiful investigation of the oscillations of a liquid globule, and the vibrations of a jet, and also the lucid set of papers in which Laplace's theory of Capillarity is explained, criticised, and amended. Reference may also be made to the theory of "group-velocity." The discrimination between this and wave-velocity had been made by Scott Russell, and the group-velocity had been identified by Reynolds with the rate of transmission of energy, for the case of water-waves. A general proof applicable to any type of wave-motion was given by Rayleigh, who also pointed out the importance of the conception in various fields.

The mathematically elegant theory of discontinuous motions in frictionless liquids had been started by Helmholtz and Kirchhoff in two classical papers. The work of the latter suggested to Rayleigh a theory of the resistance experienced by a plane lamina moving through a stream, and he completed Kirchhoff's solution from this point of view. The results, though necessarily imperfect as a picture of what really takes place, were a great improvement on previous explanations, and have stimulated much subsequent investigation. A cognate subject to which Rayleigh devoted much attention, partly no doubt owing to its acoustical bearings, and later for its own sake, was the question of stability of fluid motions. It had been remarked by Helmholtz, and further insisted on by Kelvin, that a surface of discontinuity would in a frictionless liquid necessarily be unstable. Rayleigh's first enquiry was: to what degree is the instability affected if the discontinuity is eased off, as it actually is by viscosity? He found that the instability remains for disturbances whose wave-length exceeds a certain limit. He further investigated the flow between parallel planes, and later in a pipe, having in view Reynolds's experimental demonstration of a critical velocity. The motion proved to be stable provided the graph of the velocity, as a function of the distance from the axis, is free from inflexions. Rayleigh was well aware that this conclusion must not be pressed too far. The disturbances contemplated are assumed to be infinitesimal; moreover, although the type of steady motion is such as could be maintained (if there were no disturbance) under the influence of viscosity, the effect of friction on the *disturbed* motion is in fact neglected. In particular, the condition of no slipping at the walls, which appears to be fundamental, is violated. Calculations of the above type were resumed at frequent intervals, and his more recent papers include a masterly review of the subject, in which viscosity is duly considered.

The most casual inspection of the contents of any one of the six volumes of his collected papers will show what large fields of Rayleigh's activity have here been left unnoticed. The electrical researches, for instance, important as they often are from a mathematical as well as a physical point of view, have not even been mentioned. But the main characteristics of the work are the same throughout. If asked to describe in one word the essential character of his genius, we should say that it was in the highest degree *illuminating*. Whatever the subject taken up, not only is new material contributed, but existing knowledge is reviewed and set in a fresh light, unsuspected analogies and affinities are revealed, and what was often a collection of disconnected fragments becomes an orderly and massive structure. His mind was of a type which we like to think of as peculiarly British, and he maintained to the full the tradition of the great dynamical school of which he was the most conspicuous surviving representative. He died on June 30th, 1919.

H. L.