KARIAMANIKKAM SRINIVASA KRISHNAN*

1898-1961

Foundation Fellow 1935

INDIA lost a distinguished physicist and philosopher in the death, after a third heart attack, of KARIAMANIKKAM SRINIVASA KRISHNAN. His contributions to science and his achievements especially in physics won international recognition for India.

Krishnan was born on 4 December 1898, in the village of Watrap, in the Tirunelveli (now Ramnad) District of Tamilnad (Madras State). His father was a Brahmin farmer-scholar of the old school, deeply versed in Tamil and Sanskrit religious literature, who spent a good part of his time in pilgrimages to South Indian temples, particularly to Srirangam and Tirupathi. From him Krishnan inherited an abiding love of religion and philosophy and a thorough knowledge of the Tamil language and literature, and of Sanskrit. His mother was very intelligent and an excellent organizer.

His early schooling was in the rural surroundings of his native village and at the Hindu High School at nearby Srivilliputtur. In a broadcast talk on All India Radio he once described the palm-leaf manuscript of which, in the first standard, two or three leaves were written every day until by the end of the year it had become a good-sized 'book' containing a vast amount of general information. It included, among other things, formulae for identifying the constellations in the night sky and mnemonics for determining time from the position of the constellation nearest to the zenith. This, he said, was not merely book knowledge but was accompanied by actual observations on the night sky. It was typical of Krishnan's encyclopaedic memory that late in life, when confronted with a question on astronomy, he was able to give a convincing answer from his recollection of the palm-leaf manuscript.

His subsequent education was partly in the American College, Madura, and then in the Christian College, Madras, where, after taking his degree in physics, he became a Demonstrator in Chemistry. He was meticulous in seeing that every fresh student knew exactly how to make observations and how to record the results of experiments. In later life he himself took much trouble to write both tersely and lucidly. At the request of some of the students he began an informal lunch-hour discussion to which they could bring any questions in physics, mathematics or chemistry. After a time so many students came from other Madras colleges that even the big gallery of the lecture room was full to overflowing. One of his students, who

*Reproduced from the *Biographical Memoirs of Fellows of the Royal Society*, Volume 13, 1967.

afterwards became Principal of Andhra University College, Waltair, has written: 'I learnt more physics in that half an hour in Krishnan's class than during the rest of the regular lectures, as his explanation of physical concepts was wonderfully lucid.' He was also much loved for his kindly and sympathetic manner.

In 1920 Krishnan went to Calcutta, attracted by the fame of the growing school of physics being developed by Professor C. V. Raman at the University College of Science. There he attended post-graduate classes, but showed such a keen interest in and aptitude for research in optics and molecular physics that Raman, realizing Krishnan's abilities, took him as a Research Associate in the Indian Association for the Cultivation of Science, 210 Bowbazar Street, where he at first lived with other young research workers in the dormitories. Here, it was said, he could hold his room-mates spell-bound with tales from the epics and of the ancient saints and philosophers. His day in the laboratory began at 6 a.m., often after an early walk and a cold bath. As he was a great football fan, many an evening would be spent with his colleagues watching a match in the Eden Gardens. He also used to take a very lively interest in political movements and personalities, and was a strong nationalist. At one time he thought it unbecoming to go abroad in search of Western learning and even took to writing his scientific papers in Tamil; but time mellowed him in this respect (although he always retained a spirit of sturdy independence of thought and action) and he grew to love Western literature. He was a voracious reader all his life and afterwards said (in the broadcast previously mentioned, published in the *Souvenir* in honour of his 60th birthday, 1958):

> 'Walter Scott, Dickens, Thackeray, Stevenson, Cervantes, Dumas and Victor Hugo and Conan Doyle linger in my memory as my favourite authors at this time, Plato and Aristotle in translations, Shakespeare, Milton and Shelley, Swift, Addison, Boswell, Newman, Mathew Arnold, Walter Pater and Charles Lamb at a later age and Tolstoy, Ibsen and Bernard Shaw still later. Some of them naturally stand out much more prominently than others in my memory. I should specially mention *Don Quixote*, *Pickwick Papers*, *Vanity Fair* and *Book of Snobs*, *Essays of Elia*, *Essay and Discourses* of Stuart Mill, some of the prose writings of Swift and Whitehead, *Alice in Wonderland* and *Through the Looking Glass*, most of which I have re-read later.
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> 'Among the popular scientific books that made a great impression on me I should specially mention Tyndall's *Fragments*, *Microbe Hunters* by Paul de Kruif, *Men of Mathematics* by Eric Bell, *A Mathematician's Apology* by Hardy, and the biographies of Kelvin, Helmholtz, Lord Rayleigh, Maxwell and Tait.
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> 'Among the serious scientific writings, the collected papers of Lord Rayleigh have been my constant companion for nearly 38 years and I can-

> not think of a better model for a research worker. One of the research papers of Einstein I have read off and on during the same period, and every time I read it I get something new out of it. Some of the papers of Niels Bohr had over me even more profound influence.'

All this he could take in his stride without the least interruption to the quality or quantity of his scientific work. Given the opportunity by Professor C. V. Raman, who was a source of great inspiration to all his students, Krishnan plunged deeply into an experimental study of the scattering of light in a large number of liquids, and its theoretical interpretation; he also began work on the magnetic anisotropy of gaseous molecules and of crystals (nitrates and carbonates). He collaborated with Raman in making a detailed examination of the changes in the frequency and polarization of light which was found to be associated with molecular scattering. These concentrated studies led to the discovery of the *Raman effect* in 1928.

In October 1928 Professor A. Sommerfeld visited Calcutta and gave a course of seven lectures on 'Modern developments in wave mechanics'. Krishnan took careful notes and undertook the task of preparing the lecture course for publication by Calcutta University as a book. In so doing he developed five of the lectures in an independent way and was commended by the visiting Professor for his originality and scholarship in supplying elegant mathematical proofs.

From 1929 to 1933 Krishnan served as a Reader in Physics at Dacca University where he found a very congenial atmosphere for teaching and research, with Professor S. N. Bose as Head of the Physics Department. Here he turned his attention to the subject of magnetic properties of crystals in relation to their structure, and developed elegant and precise experimental techniques to measure the magnetic anisotropy of dia- and paramagnetic crystals. He was able to correlate the anisotropy of crystals with the anisotropy and arrangement of the individual molecules or ionic groups. In suitable cases, from magne-crystallic measurements, the orientation of molecules in the unit cell could be determined. Krishnan and his students also developed methods for the accurate measurement of feeble susceptibilities and anisotropies. The papers he published during this period in collaboration with B. C. Guha, S. Banerjee and N. C. Chakravorty were the foundation stones of the modern fields of crystal magnetism and magnetochemistry.

Krishnan was invited in 1933 to take up the post of Mahendralal Sircar Professor of Physics in the Indian Association for the Cultivation of Science, Calcutta. This infused in him a new enthusiasm and a fresh impetus. With Mookherji and Bose as co-workers, he continued vigorously the study of the magnetic properties of the salts of the rare earth and iron groups and integrated the results of measurements on the crystalline electric fields of crystals with the theoretical conclusions of Van Vleck, Penney and Schlapp. Many of his papers on magne-crystallic action were published in the *Philosophical*

Transactions of the Royal Society. At about the same time, Ganguli and Krishnan, in a classic paper in the *Proceedings of the Royal Society* (1941), established that the diamagnetism of graphite is very large indeed along the hexagonal axis and that certain of the electrons in such a crystal form a two-dimensional electron gas. Further, from the temperature-variation study, they concluded that the energy distribution of electrons in graphite obeyed Fermi-Dirac statistics.

The outstanding achievements of Krishnan could not remain unnoticed. He was invited by Lord Rutherford to the Cavendish Laboratory, Cambridge, and by Sir William Bragg to the Royal Institution, London, to give course of lectures in 1937. The Liège University Medal was awarded to Krishnan as a recognition of his scientific achievements.

Krishnan became the Professor of Physics in the University of Allahabad in 1942. Here he was concerned with teaching and research. In discussion with senior students, he reviewed in a systematic way various problems of the classical scattering of light, X-rays and electrons, of quantum theory, wave mechanics and statistical thermodynamics. Together with his students, he was able to carry out some important investigations in these subjects in spite of administrative duties and war-time difficulties.

Krishnan undertook a theoretical investigation in collaboration with A. B. Bhatia on the electrical conductivities of metals and alloys. He found that the scattering of electrons can be almost wholly attributed to local thermal fluctuations in density of the type studied by Smoluchowski and Einstein. This study could be easily extended to binary alloys also. In the case of alloys, the large increase in the resistivity due to alloying was shown to be due to fluctuations in the concentration of the alloying metal rather than to fluctuations in density. With this, a simple approach was found for discussing the electrical properties of metals and alloys as order-disorder phenomena.

Then came independence for India and its new leaders saw in Krishnan an outstanding senior scientist of international reputation. He was offered the Directorship of the National Physical Laboratory, New Delhi, which he accepted, though it meant sacrificing his natural desire for teaching. The post carried with it large administrative responsibilities. These did not deter Krishnan from continuing his activities in his chosen fields of research. With S. K. Roy, he analysed the differences between the characteristic frequencies which appear in dispersion formulae and published a series of papers in the *Proceedings of the Royal Society* and elsewhere which resolved certain doubts regarding the original formulae of Drude and Lorentz and gave many new and significant results.

At the National Physical Laboratory Krishnan also turned his attention to problems in the thermionics in collaboration with S. C. Jain. He suggested a new method of determining the saturation pressure of electrons by passing them through a small aperture in a wall of a uniformly-heated graphite chamber whose inside could be coated by any metal. This was a new

technique which avoided the need for degassing the surface of a metal and, at the same time, allowed the determination of the thermionic constants and their temperature coefficients. In particular, the data for the monovalent and transition metals present some interesting features inasmuch as the method is analogous to that of obtaining black-body radiation which is independent of the emissivity of the walls of the chamber.

He devoted both theoretical and experimental attention to the study of the distribution of temperature along a thin rod or wire which is electrically heated *in vacuo*. The temperature distribution was found to be parabolic near the centre, logarithmic a little farther away and approximately similar to that of an infinitely long filament near the ends. These studies have a practical application to modern industry in connexion with electrical technology.

The problem of temperature distribution along a heated tube was also solved by Krishnan and Sundaram. They calculated, in a straightforward way, the radiative transfer of energy in the hollow core of the tube. The expression they obtained bears a close similarity to that of the lattice conductivity of a dielectric cylinder at very low temperatures, in which the diffusion of the phonons is responsible for conduction and their free path is also determined, as in this case, by the diameter of the cylinder.

In the last few years of his life he gave much thought to obtaining an integrated picture of the problems of the solid state.

Krishnan loved mathematical reasoning and his skill as a mathematician would have gained him international recognition even without his great ability as an experimental physicist. He was deeply moved by a by-product of pure mathematical interest thrown up during the course of a physical investigation. At the same time, although a pure scientist himself, he strongly deprecated any division between pure and applied mathematics or science and when, in 1955, the U.S. National Academy of Sciences invited him to be the guest speaker at their Annual Dinner (a privilege that only the Presidents of the Royal Society, of the Royal Netherlands Academy and of the Swedish Academy had previously enjoyed) he seized the opportunity of extolling the purely cultural values of technological training and showed how India was trying to improve this aspect of her national life. Professor Van Vleck said afterwards of his speech: 'He quoted extensively from Whitehead and it was his speech that prompted me to read some of Whitehead's writings'.

Krishnan also believed firmly that international cooperation in science was one of the best ways of promoting understanding between nations and he was himself an ideal ambassador for India because his humility, simplicity and humour, combined with his scientific and cultural erudition and an all-too-rate fund of common sense won him friends all over the world. He never lacked an appropriate anecdote with which to drive home a moral or disarm a critic, or just to entertain. Nehru once remarked that he did not remember meeting Krishnan on any occasion when he had not told him

some new story. But Nehru also said of him on his sixtieth birthday: 'He is a great scientist, but something much more. He is a perfect citizen, a whole man with an integrated personality.'

Krishnan was the recipient of many honours both in India and abroad. He was elected a Fellow of the Royal Society, London, in 1940 and was knighted in 1946. He was associated with the work of many national and international scientific bodies: Chairman, Scientific Advisory Committee, UNESCO; Vice-President, International Council of Scientific Unions and of the International Union of Pure and Applied Physics; Chairman, Indian National Committee, URSI; Chairman, Indian National Committee for IGY and Chairman, Sub-Commission for Cooperation with UNESCO. He was, with P. P. Ewald, M. v. Laue and W. L. Bragg, a Founder-Member of the International Union of Crystallography, and afterwards a member of its Executive Committee. In 1956, Krishnan was elected a Foreign Associate of the U. S. National Academy of Sciences; in 1959 he was the guest speaker at the Geneva Convention of the International Telecommunications Union.

Dr. Krishnan had an active association with the work of many scientific organizations and establishments in India. He was President, Section of Physics, Indian Science Congress in 1940 and its General President in 1949. He was President also of the National Academy of Sciences and of the National Institute of Sciences. He was the Chairman, Board of Research in Nuclear Science; Member, Atomic Energy Commission, Board of Engineering Research, Standing Board of Astronomy and the University Grants Commission. He served the Council of Scientific and Industrial Research from its very inception in various capacities, as a member of the Governing Body and the Board of Scientific and Industrial Research, and on many of its Research Committees. As a member of the Editorial Board, he contributed significantly to the growth and progress of the *Journal of Scientific and Industrial Research*.

The title of Padma Bhushan was awarded to him by the President of India in 1954, and he was the first recipient of the Bhatnagar Memorial Award in March 1961. The Government of India honoured Krishnan by appointing him a National Professor—an honour which he shared with a very few great Indian scholars. But he did not live long to enjoy this honour. Just before he died he was planning to take the first long leave of a lifetime, to visit a son in England and a daughter in the U.S.A., whose little son he had never seen. He loved playing with his grandchildren at home.

He left behind him his wife, two sons and four daughters.

(The first draft of this notice was prepared by the late Dr. H. J. Bhabha, F.R.S., and was found amongst his papers late in 1966.)

KATHLEEN LONSDALE

H. J. BHABHA

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