# Debendra Mohan Bose (1885–1975) – an eminent physicist of India

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*Debendra Mohan Bose was one of the leading experimental physicists of India in the 20th century. He did notable work with Wilson cloud chambers, successfully photographing the recoil tracks of radioactive nuclei during the process of alpha-emission. He earned international eminence for his contributions in the field of simple and complex compounds containing paramagnetic and rare-earth ions and for the determination of the mass of $\mu$-mesons using the photographic emulsion method. He was also responsible for initiation of research in India in the areas of cosmic rays, artificial radioactivity and neutron physics. He was a member of the committee which recommended the formation of the Atomic Energy Commission in India. He was also a member of the CSIR committee which planned the setting up of the National Physical Laboratory and the National Chemical Laboratory.*

In the golden era of the science movement in India, many great scientists were born in the country and their stupendous achievements have been a source of eternal pride for us. Debendra Mohan Bose is one of them. His contributions in physics are phenomenal. For the benefit of the students of the present and future generations in physical sciences, it has great relevance. Hence this small effort to unveil a man and a scientist of high stature.

## Childhood, family history and early education

Bose was born on 26 November 1885 in Calcutta in an enlightened Brahmo family. His father Mohini Mohan Bose was a homeopathic physician trained in USA. His mother Subarnaprova Bose was inclined towards child welfare. One of his paternal uncles, Ananda Mohan Bose, was the first Indian Wrangler in the Mathematical Tripos of Cambridge University. His maternal uncle was the pioneer Indian scientist, Acharya Jagadish Chandra Bose, whose discoveries in physics and botany are world renowned.

As Debendra Mohan had lost his father quite early in life, his maternal uncle J. C. Bose closely monitored his academic upbringing. After completing his school education, in 1902 Bose passed the Intermediate examination from the Presidency College, Calcutta. Because of illness resulting in the loss of one academic year, he joined Presidency College again and passed the B A examination with honours in physics in 1905. From the same institution he completed his M A in physics in 1906, standing first class first in the order of merit.

Advised by poet Rabindranath Tagore, who was a close family friend, Bose joined as a research scholar under J. C. Bose in Presidency College and also took up a teaching assignment in City College, Calcutta. After a while, his family decided to send him to England for higher studies.

## Higher education and academic career

In 1907, D. M. Bose joined Chirst's College in Cambridge, UK, as an advanced level student. While in Cambridge, he worked in the famous Cavendish Laboratory under the guidance of the physicist J. J. Thomson (1856–1940). C. T. R. Wilson (1869–1959) tutored him in the practical classes. At that time, Wilson was involved in his path-breaking work of developing the cloud chamber, for which he was later awarded the Nobel Prize. Wilson's influence inspired D. M. Bose later in his academic life and led him to develop the Wilson chamber indigenously. In 1910, D. M. Bose joined the Royal College of Science in London. In 1912, he obtained the B Sc degree with first class in physics from London University.

At that time, Asutosh Mookerjee was the Vice-Chancellor of Calcutta University. In 1914, after D. M. Bose returned to Calcutta, Mookerjee recruited him as the Rashbehari Ghosh Professor in the newly set up Physics Department of the University. The same year, D. M. Bose was awarded the 'Ghosh Traveling Fellowship' for pursuing higher studies abroad. He went to Berlin, then the most vibrant place for doing research in physics. He joined the laboratory of E. Regener (1881–1955), who was famous primarily for the design and construction of instruments to measure cosmic ray intensity at various altitudes. At that time, the First World War broke out in Europe. As a consequence, D. M. Bose was confined in Germany for nearly five years. However, his academic pursuits did not suffer. He continued with his research work and got involved with the construction of a new type of Wilson cloud chamber. Using the cloud chamber, he recorded the tracks of ionizing alpha and beta particles from radioactive sources. His training under Wilson turned out to be useful. It helped him to build this new type of cloud chamber. Using it he successfully photographed the tracks of recoil protons produced during the fast-moving alpha particles in a hydrogen-filled chamber. The results of the experiment provided verification of Darwin's formula for collision between fast-moving charged particles and molecules. D. M. Bose also successfully photographed the recoil tracks of delta-particles which were discovered by Bumstead. The preliminary results of this experiment were published in German language[1]. The full and complete research paper on these findings was again in German language[2].

In a letter dated 7 November 1973, Thaddesus J. Trenn, University of Regensburg, Germany wrote to D. M. Bose, 'I am completing a historical analysis of the use of cloud chamber techniques … it is now evident that the results which D. M. Bose had obtained during 1914–1918, by procuring the first photographic records of artificial disintegration, were certainly and clearly precursors of P. M. S. Blackett's (1897–1974) recoil related work.'

The five years that D. M. Bose was forced to spend in Germany, became a boon for him. That was the most exciting time of modern physics and most of the new developments in the discipline were taking place in Germany. Fortunately, during that time, D. M. Bose got the opportunity of attending the colloquia of Max Planck (1858–1947), Robert Pohl (1884–1976), Max Born (1882–1970), Emil Warburg (1846–1931), J. Franck (1882–1964), Rubens (1865–1922) and many others. Various branches of this new physics such as general and special relativity, quantum theory, etc. were being developed in Germany at that time. The leaders of this new scientific movement were the most brilliant scientists of our time, men like Albert Einstein (1879–1955), Max Planck, A. J. W. Sommerfeld (1868–1951) and others. In 1919, D. M. Bose secured his Ph D from Humboldt University in Berlin. His work in the thesis received high honours. After a brief stopover in England, in 1919, he finally returned to Calcutta and joined the Physics Department in Calcutta University. At that time, the department was virtually star-studded, C. V. Raman being the brightest amongst them all. Raman was the Palit Professor and Head of the Department of Physics. A brilliant group of young lecturers like P. N. Ghosh, S. N. Bose, M. N. Saha and S. K. Mitra had all been recruited by the dynamic visionary Asutosh Mookerjee. D. M. Bose taught kinematics, statistical mechanics and X-rays at the postgraduate level.

With regard to his teaching abilities, it would be pertinent to quote P. C. Mukherji, one of his physics students, who later became the Director of Public Instructions, West Bengal. He wrote: 'In August, 1930, when we started M Sc class in Physics, we were lucky to read Dynamics under the guidance of Dr Bose … when we not only read Dynamics but learnt the technique of how to grasp the theory portion of Physics with austerity and solidarity. It may be mentioned in this connection that Dr Bose, when in Berlin, had the good chance of attending the full course of lectures by Planck and Einstein … and our course was adapted from the lectures on General Mechanics by Max Planck. We came in direct contact of Prof. Bose when we started experiments in X-rays and crystal structure next year … Dr Bose who guided us there. Here we found in him the strictness and rigidity under which we had to work daily … In concluding I would like to thank my stars that I could associate myself with such a sincere, noble-hearted, selfless teacher of such eminence and repute. I regard him as a lofty-minded *Guru* of the old days.'

On the research side, D. M. Bose carried out his investigations with the cloud chamber. As already mentioned, he had built a cloud chamber indigenously. With his student S. K. Ghose, he photographed the recoil tracks of radioactive nuclei during the process of alpha-emission. He was able to recognize the simultaneous emission of two ionizing electron tracks from a helium atom due to collision with an alpha-particle. In one of his photographs, the earliest evidence of disintegration of nitrogen nucleus under alpha-particle bombardment has been recorded. The photograph published under the title 'Tracks of a particle in helium'[3] was highly acclaimed by E. Rutherford (1871–1937)[4]. As stated earlier, this finding was clearly a precursor to P. M. S. Blackett's (1897–1974) future work on recoil. D. M. Bose guided and trained a large number of students such as H. P. De, R. L. Sengupta, M. S. Sinha, S. D. Chatterjee, N. K. Saha, P. Ray and many others. They used the cloud chamber and made original important contributions in the field of nuclear collisions and disintegration.

D. M. Bose and Biva Choudhuri did commendable work on cosmic rays with photographic emulsion. Between 1939 and 1942, they carried out experiments under different geographical and chemical conditions and observed a number of long, curved ionization tracks[5]. These appeared to be different from the ionization tracks due to alphas or protons. By measuring the mean scattering and mean grain spacing of the track-producing particles, D. M. Bose and Choudhuri developed a technique for determining their mass. They were able to prove that such tracks were being produced by particles having a mass, 216 times the mass of an electron. These were actually the first analysed tracks of the meson. Unfortunately, D. M. Bose and Choudhuri had to abandon their research work in this area as they found it hard to get the standardized emulsion, because of the ongoing Second World War in Europe. Later in 1945, C. F. Powell (1903–1969) followed the same method devised by D. M. Bose and Choudhuri and discovered the tracks of the meson. He was awarded the Nobel Prize for his discovery. In 1947, following the same procedure Powell announced the existence of two kinds of mesons $\mu$ and $\Pi$, having masses 214 and 290 $m_e$ respectively. Though Powell won the Nobel Prize, the impact of the work of Bose and Choudhuri can never be denied.

In his famous work entitled 'The study of elementary particles by the photographic method', Powell acknowledged D. M. Bose and Choudhuri and wrote: 'In 1941, Bose and Choudhuri had pointed it out that it is possible, in principle, to distinguish between the tracks of protons and mesons in an emulsion … They concluded that many of the charged particles arrested on their plates were lighter than protons, their mean mass being 200 $m_e$ … the physical basis of their method was correct, and their work represents the first approach to the "scattering method" of determining momenta of charged particles by observation of their tracks in emulsion.' D. M. Bose earned international eminence for his important contributions in the field of simple and complex compounds containing paramagnetic and rare-earth ions and the determination of the mass of μ-mesons by the photographic emulsion method.

After the discovery of quantum mechanics and publication of Neils Bohr's (1885–1962) theory of atomic structure, hectic research work in the related area took place all over the Western world. Using Bohr's theory of distribution of electrons in shells and sub-shells, calculation of the spectroscopic terms of an atom or positive ions in the ground and excited state was possible. Calculation of the nature of their emission and corresponding absorption spectra was also feasible. In 1925, F. H. Hund (1896–1997) proposed a formula for calculating the magnetic moments of elements. In the rare-earth group of ions, the values of the magnetic moments calculated by Hund were in excellent agreement with the experimentally determined values. But Hund's formula could not correctly predict the magnetic moments of iron, cobalt or nickel. D. M. Bose, on the other hand, in his paper written in German[6] proposed a rule for calculating magnetic moments of sixfold and fourfold complex (coordination) compounds, which gave the criterion to differentiate between different types of such compounds[7]. D. M. Bose in his paper titled 'On the magnetic moments of ions of the transitional group of elements'[8] showed that if an assumption was made that in such transition elements, that is, in paramagnetic ions, only the spin moments of the electrons contributed to the magnetic moment, then a better agreement could be obtained[9]. The magnetic moments of compounds of the transition series (Ti to Cu), as regards consideration of experimental values agreed well with the proposed 'spin-only' formulation of D. M. Bose. Later, in 1929, E. C. Stoner (1899–1968) and J. H. Van Vleck (1899–1990) provided the necessary theoretical explanation[10]. The 'Bose–Stoner' hypothesis may be summarized as follows: Stoner's theory is a theory of metallic ferromagnetism. Bose excitations are spin-waves in these systems[11].

Hans Bethe (1906–2005) and Van Vleck proposed a quantum mechanical theory of the magnetic properties of the compounds of the iron group of elements. D. M. Bose along with his students S. Dutta, M. Deb and P. C. Mukherji performed a series of experiments to obtain experimental proof of the Bethe–Van Vleck quantum mechanical theory of the degenerate orbital quantum number of a paramagnetic ion.

Soon D. M. Bose became interested in the studies of ultrasonics. In collaboration with T. C. Bhadra, he carried out a series of experiments to investigate and understand the theory of the mechanism of ultrasonic radiation in liquid.

D. M. Bose has published nearly 40 original research papers in different branches of physics. Almost all of them were published in reputed international journals; 12 of them were published in *Nature*.

His research contributions may be broadly classified under the following categories:

(a) Study of nuclear collision and disintegration using Wilson cloud chamber and photographic emulsion.

(b) Study of properties of simple and complex compounds containing paramagnetic and rare-earth ions. Interpretation of their magnetic properties in terms of Bohr magneton. Discovery of a new photo-magnetic effect.

(c) Study of material physics using microwaves and ultrasonics.

(d) Initiation of research in India in the fields of cosmic rays, artificial radioactivity and neutron physics.

In 1927, D. M. Bose and M. N. Saha attended the International Congress of Physics at Lake Como, Italy. The conference featured 60 invited participants from 14 countries, including 11 Nobel laureates. This is a pointer to the acclaim that both of them had earned in the world of science. In 1933, D. M. Bose revisited London representing India in an International Congress on 'Liquid Crystals'.

After taking charge of the Bose Institute, as its director, in 1938, he shifted his field of research from physical to biological sciences and made valuable contributions in the area of plant physiology. But since this note is dedicated to D. M. Bose, the physicist, his contributions in plant sciences are not mentioned here. Incidentally, D. M. Bose also made valuable contributions to the 'history of science'.

## Service profile and honours

D. M. Bose served the Physics Department in the University of Calcutta from 1914 to 1934 as the Rahbehari Ghosh Professor. After Raman left for Indian Institute of Science (IISc), Bangalore to take up the Directorship there, D. M. Bose succeeded him as the Palit Professor of Physics and continued in that position till 1937. After the demise of J. C. Bose, D. M. Bose left Calcutta University and in 1938 took charge as the Director of Bose Institute in Calcutta. He was a member of the committee which recommended the formation of the Atomic Energy Commission (AEC) in India. The AEC was formed in 1947 by the Government of India, and D. M. Bose obtained for the Bose Institute block grants from the AEC for research in nuclear physics, cosmic rays, construction of high-powered neutron generator, etc. He obtained research grants for applied research in botany from ICAR, specially for radiation mutation work to improve cash crops like jute and oilseeds. He inspired scientists in the Bose Institute to take up construction of sophisticated instruments like Tisselius apparatus, liquid gas chromatograph, $^{14}$C-dating apparatus, long $BF_3$-counters, high-pressure ionization chambers, counter-controlled rectangular cloud chambers of large volume, X-ray crystallographic apparatus and various electronic circuits associated with nuclear and neutron physics-related research works. He started the first microbiology department in India. D. M. Bose, along with K. S. Krishnan, M. N. Saha and S. Bhatnagar was a member of the CSIR committee which planned the setting up of the National Physical Laboratory and the National Chemical Laboratory. He was one of the founder members of the Indian Physical Society; a life member of the Indian Association for the Cultivation of Science and was once elected as President of the Asiatic Society of Bengal. From the time of its inception, D. M. Bose was deeply involved with the Indian Science News Association. For a long time, he was editor-in-chief of *Science and Culture.* He was a founder Fellow of the Indian National Science Academy. He received numerous honours in India and abroad for his outstanding and original contributions in science. He was awarded the D Sc (*Honoris Causa*) by the Universities of Calcutta and Jadavpur. The Visva-Bharati University conferred on him their greatest award the *Desikottama.*

In 1967, D. M. Bose resigned from the Directorship of the Bose Institute, but he continued to be its mentor and adviser. He passed away on 2 June 1975 in Calcutta.

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