Satyendra Nath Bose: A Pioneer of Quantum Mechanics

DR. JAI NANDAN SINGH
H.O.D MATHEMATICS
KOSHI COLLEGE KHAGARIA
T.M.B.U. BHAGALPUR

Abstract: -

Satyendra Nath Bose was an Indian physicist and Mathematician who is considered one of the fathers of quantum mechanics. He made significant contributions to the development of this field, particularly in the area of statistical mechanics. Bose's work on the Bose-Einstein condensate, a state of matter in which atoms behave collectively as a single entity, has had a profound impact on our understanding of the whole universe.

Satyendra Nath Bose, a pioneer of quantum mechanics. Satyendra Nath Bose, an eminent Indian physicist, is renowned for his groundbreaking work in quantum mechanics, particularly his collaboration with Albert Einstein in developing the foundation for Bose-Einstein statistics and the theory of the Bose-Einstein condensate. His contributions have had a profound impact on our understanding of the quantum world.

Keywords: - Physicist, Mathematician, Significant, Contribution, statistical, Mechanics.

Introduction: -

Born on January 1, 1894, in Calcutta (now Kolkata), India, Bose displayed exceptional intellectual abilities from a young age. He excelled in his studies and graduated with honors from the University of Calcutta. His academic journey was marked by a deep interest in mathematics and physics, which would later shape his scientific career.

Dhaka

After his stay in Europe, Bose returned to Dhaka in 1926. He did not have a doctorate, and so ordinarily, under the prevailing regulations, he would not be qualified for the post of Professor he applied for, but Einstein recommended him. He was then made Head of the Department of Physics at Dhaka University. He continued guiding and teaching at Dhaka University and was the Dean of the Faculty of Science there until 1945.

Bose designed equipment himself for an X-ray crystallography laboratory. He set up laboratories and libraries to make the department a center of research in X-ray spectroscopy, X-ray diffraction, magnetic properties of matter, optical spectroscopy, wireless, and unified field theories. He also published an equation of state for real gases with Meghnad Saha.

Calcutta

When the partition of India became imminent (1947), he returned to Calcutta and taught there until 1956. He insisted every student design their own equipment using local materials and local technicians. He was made professor emeritus on his retirement. He then became Vice-Chancellor of Visva-Bharati University in Santiniketan. He returned to the University of Calcutta to continue research in nuclear physics and complete earlier works in organic chemistry. In subsequent years, he worked in applied research such as extraction of helium in hot springs of Bakreshwar.

Other fields :-

Apart from physics, he did research in biotechnology and literature Bengali and English. He made studies in chemistry, geology, zoology, anthropology, engineering and other sciences. Being Bengali, he devoted significant time to promoting Bengali as a teaching language, translating scientific papers into it, and promoting the development of the region.

Honours :-

Bose with other scientists at the University of Calcutta Bust of Satyendra Nath Bose which is placed in the garden of Birla Industrial & Technological Museum In 1937, Rabindranath Tagore dedicated his only book on science, Visva-Parichay, to Satyendra Nath Bose. Bose was honoured with the title Padma Vibhushan by the Indian Government in 1954. In 1959, he was appointed as the National Professor, the highest honour in the country for a scholar, a position he held for 15 years. In 1986, the S.N. Bose National Centre for Basic Sciences was established by an act of Parliament, Government of India, in Salt Lake, Calcutta.

Bose became an adviser to the then newly formed Council of Scientific and Industrial Research. He was the president of the Indian Physical Society and the National Institute of Science. He was elected general president of the Indian Science Congress. He was the vice president and then the president of Indian Statistical Institute. In 1958, he became a Fellow of the Royal Society. He was nominated as member of Rajya Sabha. Partha Ghose has stated that !

Bose's work stood at the transition between the 'old quantum theory' of Planck, Bohr and Einstein and the new quantum mechanics of Schrödinger, Heisenberg, Born, Dirac and others.

Nobel Prize nomination :-

Bose was nominated by K. Banerjee (1956), D.S. Kothari (1959), S.N. Bagchi (1962), and A.K. Dutta (1962) for the Nobel Prize in Physics, for his contribution to Bose-Einstein statistics and the unified field theory. Banerjee, head of the Physics Department, University of Allahabad, in a letter of 12 January 1956 wrote to the Nobel Committee as follows: "(1). He (Bose) made very outstanding contributions to physics by developing the statistics known after his name as Bose statistics. In recent years this statistics is found to be of profound importance in the classifications of fundamental particles and has contributed immensely to the development of nuclear physics.

During the period from 1953 to date, he has made a number of highly interesting contributions of far-reaching consequences on the subject of Einstein's Unitary Field Theory."

Bose's work was evaluated by an expert of the Nobel Committee, Oskar Klein, who deemed his work not worthy of a Nobel Prize.

Collaboration with Einstein

Recognizing the importance of Bose's work, Einstein translated his paper into German and submitted it to the prestigious Zeitschrift für Physik on Bose's behalf. Impressed by the novel ideas, Einstein further developed Bose's statistical method, applying it to a broader range of particles. This collaboration led to the formulation of Bose- Einstein statistics, which describes the behavior of particles that do not obey the Pauli exclusion principle.

Bose-Einstein Statistics: -

While presenting a lecture at the University of Dhaka on the theory of radiation and the ultraviolet catastrophe, Bose intended to show his students that the contemporary theory was inadequate, because it predicted results not in accordance with experimental results.

In the process of describing this discrepancy, Bose for the first time took the position that the Maxwell-Boltzmann distribution would not be true for microscopic particles, where fluctuations due to Heisenberg's uncertainty principle will be significant. Thus he stressed the probability of finding particles in the phase space, each state having volume h^3, and discarding the distinct position and momentum of the particles.

Bose adapted this lecture into a short article called "Planck's Law and the Hypothesis of Light Quanta" and sent it to Albert Einstein with the following letter :-

“Respected Sir, I have ventured to send you the accompanying article for your perusal and opinion. I am anxious to know what you think of it. You will see that I have tried to deduce the coefficient $8\pi\, v^2/c^3$ in Planck's Law independent of classical electrodynamics, only assuming that the ultimate elementary region in the phase-space has the content h. I do not know sufficient German to translate the paper. If you think the paper worth publication I shall be grateful if you arrange for its publication in Zeitschrift fur Physi cs . Though a complete stranger to you, I do not feel any hesitation in making such a request. Because we are all your pupils though profiting only by your teachings through your writings. I do not know whether you still remember that some body from Calcutta asked your permission to translate your papers on Relativity in English. You acceded to the request. The book has since been published. I was the one who translated your paper on Generalised Relativity.”

Einstein agreed with him, translated Bose's papers "Planck's Law and Hypothesis of Light Quanta into German, and had it published in Zeitschrift für Physik under Bose's name, in 1924.

The reason Bose's interpretation produced accurate results was that since photons are indistinguishable from each other, one cannot treat any two photons having equal energy as being two distinct identifiable photons. By analogy if, in an alternate universe, coins were to behave like photons and other bosons, the probability of producing two heads would indeed be one-third (tail-head= head-tail).

Since the coins are distinct, there are two outcomes which produce a head and a tail. The probability of two heads is one- quarter.

Bose's interpretation is now called Bose-Einstein statistics. This result derived by Bose laid the foundation of quantum statistics, and especially the revolutionary new philosophical conception of the indistinguishability of particles, as acknowledged by Einstein and Dirac. When Einstein met Bose face-to-face, he asked him whether he had been aware that he had invented a new type of statistics, and he very candidly said that no, he wasn't that familiar with Boltzmann's statistics and didn't realize that he was doing the calculations differently. He was equally candid with anyone who asked.

Bose-Einstein condensate

“Velocity-distribution data of a gas of rubidium atoms, confirming the discovery of a new phase of matter, the Bose-Einstein condensate Left just before the appearance of a Bose-Einstein condensate. Center, just after the appearance of the condensate. Right after further evaporation, leaving a sample of nearly pure condensate.”

Einstein also did not at first realize how radical Bose's departure was, and in his first paper after Bose, he was guided, like Bose, by the fact that the new method gave the right answer, But after Einstein's second paper using Bose's method in which Einstein predicted the Bose-Einstein condensate (pictured left), he started to realize just how radical it was, and he compared it to wave/particle duality, saying that some particles didn't behave exactly like particles. Bose had already submitted his article to the British Journal Philosophical Magazine, which rejected it before he sent it to Einstein. It is not known why it was rejected.

Einstein adopted the idea and extended it to atoms. This led to the prediction of the existence of phenomena which became known as Bose-Einstein condensate, a dense collection of bosons (which are particles with integer spin, named after Bose), which was demonstrated to exist by experiment in 1995.

Legacy and Impact

Satyendra Nath Bose's contributions to physics have had a lasting impact on various fields, including condensed matter physics, quantum optics, and atomic physics. His work has not only advanced our understanding of the fundamental nature of matter but has also led to practical applications, such as lasers and superconductors.

In recognition of his groundbreaking achievements, Bose was awarded numerous honors, including the Padma Vibhushan, India's second-highest civilian award. His name is immortalized in the term "boson," which refers to particles that follow Bose-Einstein statistics.

Conclusion: -

Satyendra Nath Bose was a brilliant physicist and Mathematician of India who made fundamental contributions to the development of quantum mechanics. His work on the Bose-Einstein condensate helped to revolutionize our understanding of the behavior of matter at low temperatures. Bose was a man of great intellect and integrity, and he will always be remembered as one of the giants of science.

Refrence: -

1. Venkataraman, G (1992), Bose And His Statistics, Universities Press, p. 14, 15BN 978-81-7371- 036-0.

2. A Douglas Stone, Chapter 24, The Indian Comet, in the book Einstein and the Quantum, Princeton University Press, Princeton, New Jersey, 2013.

3. Singh, Rajinder (2016) India's Nobel Prize Nominators and Nominees - The Praxis of Nomination and Geographical Distribution, Shaker Publisher, Aachen, pp. 26-27. ISBN 978- 3-8440-4315-0.

4. Singh, Rajinder (2016) Die Nobelpreise und die indische Elite, Shaker Verlag, Aachen, pp. 24- 25. ISBN 978-3-8440-4429-4.

5. Singh, Rajinder (2016) Chemistry and Physics Nobel Prizes - India's Contribution, Shaker Verlag, Aachen. ISBN 978-3-8440-4669-4.

6. Farmelo, Graham, "The Strangest Man", Notes on Dirac's lecture Developments in Atomic Theory at Le Palais de la Decouverte, 6 December 1945, UKNATARCHI Dirac Papers, p. 331, note 64, BW83/2/257889.

7. Miller, Sean (18 March 2013). Strung Together: The Cultural Currency of String Theory as a Scientific Imaginary . University of Michigan Press. P. 63. ISBN- 978-0-472-11866-3.

8.Satyendra Nath Bose (https://www.britannica.com/biography/Satyendra-Nath-Bose) at the Encyclopædia Britannica

9.Pais, Abraham (1982), Subtle is the Lord.... The Science and Life of Albert Einstein Oxford and New York: Oxford University Press, pp. 423- 34, ISBN 978-0-19-853907-0.

10. Wali, Kameshwar C (2009), Satyendra Nath Bose: his life and times Singapore: World Scientific, ISBN 978-981-279-070-5

11. O'Connor, John J.; Robertson, Edmund F., "Satyendra Nath Bose" MacTutor History of Mathematics Archive, University of St Andrews