BIRTH CENTENARY OF RICHARD FEYNMAN: A TRIBUTE

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2018 was the birth centenary of Richard Feynman, one of the greatest theoretical physicists. He was widely regarded as the most brilliant, influential, and iconoclastic figure in his field in the post-World War II era. He was awarded the Nobel Prize in Physics jointly with Julian Schwinger and Shin'ichiro? Tomonaga in 1965 for his contributions in the field of quantum electrodynamics. His other contributions in physics include the path integral formulation of quantum mechanics, the physics of the superfluidity of supercooled liquid helium, quantum computing, Parton theory, etc.

Introduction

One of the greatest theoretical physicists Richard Feynman was born about 100 years ago in America. During his lifetime, Feynman became one of the best-known scientists in the world in the post-World War II era. He was awarded the Nobel Prize in Physics jointly with Julian Schwinger and Shin'ichirô Tomonaga in 1965 for his contributions in the field of quantum electrodynamics. Apart from quantum electrodynamics he contributed in different fields of Physics, such as path integral formulation of quantum mechanics, the physics of the superfluidity of supercooled liquid Helium, particle physics, quantum computing, Feynman diagrams, etc. He assisted in the development of the atomic bomb during World War II and acted as a member of the Rogers Commission, the panel that investigated the Space Shuttle Challenger disaster. In this article the life and contributions of Feynman will be discussed.

Early Life and Education

Richard Feynman was born in Queens, New York City on the 11th May 1918[1]. His childhood home was in the community of Far Rockaway, on the southern skirt of Manhattan. Feynman was the descendant of Russian and Polish Jews who had immigrated to the United States late in the 19th century. His father was Melville Arthur Feynman and his mother was Lucille Phillips. Financially his family was neither rich nor poor[2]. They were not religious, and by his youth, Feynman described himself as an "avowed atheist"[3]. The influence of his parents on young Feynman was remarkable. His father encouraged him to ask questions to challenge orthodox thinking, and always taught Feynman something new. Feynman had also interest in science. Before being admitted to school he learnt a great deal of science from Encyclopedia Britannica and taught himself elementary mathematics.He gained from his mother the sense of humor that he had throughout his life. He had a talent for engineering. He also set up a laboratory in his room at home where he experimented with electricity and was delighted in repairing radios. He fabricated a burglar alarm system when he was in grade school. At the age of five, his brother was born but he died only at the age of four months. When Feynman was nine years old, his sister Joan was born. Richard was very close to his sister, as they both shared a natural curiosity about the world. Joan was interested in studying astronomy and Richard encouraged his sister. Joan eventually became an astrophysicist.

Feynman was admitted to Far Rockaway High School. He was interested mainly in science and mathematics. He had little interest in other subjects. At school he approached mathematics in a highly unconventional way. For his

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proficiency in mathematics Feynman was quickly promoted into a higher mathematics class.

When Feynman was 15 years old, he taught himself trigonometry, advanced algebra, infinite series, analytic geometry, complex numbers, differential calculus and integral calculus, before he met these topics in his formal education. Realising the importance of mathematical notation, he invented his own notation for sine, cosine and tangent functions and thought them to be much better than the standard notations. However, later he realised that notation could not be a personal matter since one needed it to communicate[4, 5]. In his final year at Far Rockaway High School he won the New York University Math Championship.

After leaving school he applied to several universities for admission. But it was not easy for him to be admitted.Although his scores in mathematics and science were outstanding, his performance in other subjects was poor. There was another problem. He was a Jew and at that time there were quotas on the number of Jews that a University in the United States could admit. However, he was admitted at the Massachusetts Institute of Technology (MIT) in 1935 to study mathematics. He did not like the Mathematics course there and changed courses, taking electrical engineering. Very quickly he switched to physics. But in his second Physics course he took Introduction to Theoretical Physics, a course for graduate students. Though Feynman was very keen to study quantum mechanics, there was no course on quantum mechanics at MIT. So in the spring of 1936 he began to read the available texts on the subject with T. A. Welton, his fellow undergraduate. In the summer of 1936, returning to their respective homes, the two exchanged a series of remarkable letters as they tried to develop a version of space-time where electrical phenomena are a result of the metric of a space in the same way that gravitational phenomena are[5]. Every summer Feynman applied for summer jobs at the Bell Telephone Laboratories, but was refused despite the highest recommendations, probably because he was Jewish[5]. When he was an undergraduate student he published two papers in the Physical Review. One paper, co-authored with Manuel Vallarta, was on "The Scattering of Cosmic Rays by the Stars of a Galaxy".The other was his undergraduate thesis, on "Forces in Molecules"in which he proposed an original and enduring approach to calculating forces in molecules. He obtained his B.Sc. in 1939 after four years of study at MIT.

Towards the end of his undergraduate course Feynman desired to stay at MIT for a Ph.D. degree. But John Slater, Head, Department of Physics, MIT advised him to move to Princeton University and sent a recommendation letter to Harry Smyth, Head, Department of Physics, Princeton University in favour of Feynman. Though he had best grades in physics and mathematics, his admission at Princeton was not smooth. First, his scores in history, literature and fine arts were very poor. Second, he was Jewish. Smyth wrote to Physicist Philip Morse asking "Is Feynman Jewish? We have no definite rule against Jews but have to keep their proportion in our department reasonably small because of the difficulty of placing them."[6] Morse replied, "Feynman was indeed Jewish, but physiognomy and manner, however, show no trace of this characteristic".[6] Ultimately, Feynman was accepted by Princeton and his research supervisor was John Wheeler. His first seminar at Princeton was on Wheeler-Feynman absorber theory. Albert Einstein, Wolfgang Pauli and von Neumann were among the audience.Pauli said, "I do not think this theory can be right."Feynman took note of it and found it unsatisfactory. He then developed a new approach to quantum mechanics using the principle of least action. This approach replaced the wave model of electromagnetics developed by James Clerk Maxwell with one based entirely on particle interactions mapped in space and time. In effect, Feynman's method calculated the probabilities of all the possible paths a particle could take in going from one point to another. Einstein said that one might try to apply this method to gravity in general relativity[7]. Much later Fred Hoyle and Jayant Narlikar did that in the Hoyle–Narlikar theory of gravity[8] .

Feynman received his Ph.D. degree from Princeton University in June 1942 for his thesis entitled "The Principle of Least Action in Quantum Mechanics". He had applied the principle of least action to problems in quantum mechanics. This led the foundation of the path integral formulation and Feynman diagrams.[9] A key insight was that positrons behaved like electrons moving backwards in time.

In the early 1940s a problem, now known as the Feynman's sprinkler problem, began to circulate in the Physics department of Princeton University. Feynman was interested in the problem and built an experiment in the cyclotron laboratory of the university. But he did not describe the results of his experiment and explained the physics behind the problem. He objected to name the problem as Feynman problem as it was discussed in Ernst Mach's textbook 'The Science of Mechanics', first published in 1883. The sprinkler problem attracted a great deal of attention after the incident was mentioned in 'Surely You're Joking, Mr. Feynman!'.

Career

During final year of his research Feynman was invited to work in the atomic bomb project (which was later known as the Manhattan project) at Princeton University and he worked there during 1941-42. His work in the project was to develop a theory of how to separate U^{235} from U^{238}, which is required for atom bomb. In early 1943 Robert Oppenheimer established the new secret laboratory at Los Alamos, New Mexico, where atomic bombs would be designed and built. Feynman was appointed in the laboratory in the theoretical division headed by Hans Bethe. He devised with Hans Bethe the formula, known as the Bethe–Feynman formula, for predicting the energy yield of a nuclear explosive. Bethe was highly impressed on Feynman and made him a group leader. At Los Alamos he became the youngest group leader in the theoretical division of the Manhattan Project.Feynman also took charge of the project's primitive computing effort to process the vast amounts of numerical computation required by the project. He observed the first detonation of an atomic bomb on July 16, 1945, near Alamogordo, New Mexico. Though his initial reaction was euphoric, he later felt anxiety about the force he and his colleagues had helped unleash on the world. Feynman was sent to the Clinton Engineer Works in Oak Ridge where the Manhattan Project had its uranium enrichment facilities. Here he assisted the engineers to store the materials safely so that no accident occurs. He developed a series of safety recommendations for the various grades of enrichments[10]. After returning to Los Alamos he was given the charge of the group who were working on the proposed uranium hydride bomb. It was proved to be infeasible[11].

In August 1944 Feynman was offered to join Cornell University and in 1945, after the end of World War II, he joined there as an Associate Professor of Theoretical Physics. Here he conducted research work on quantum electrodynamics. In 1950 he became Professor of Theoretical Physics at the California Institute of Technology (Caltech), where he remained the rest of his career.He was appointed Richard Chace Tolman Professor of Theoretical Physics there in 1959.

In 1957 Feynman was being considered for a position on Eisenhower's President's Science Advisory Committee, a very high level advisory board created in the wake of Sputnik. But he was not appointed due to an FBI report.FBI interviewed a woman close to Feynman who, on August 8, 1958, sent a written statement to J. Edgar Hoover, the first Director of the Federal Bureau of Investigation (FBI) of the United States : "I do not know—but I believe that Richard Feynman is either a Communist or very strongly pro-Communist—and as such a very definite security risk. This man is, in my opinion, an extremely complex and dangerous person, a very dangerous person to have in a position of public trust…."[12]. However, the government sent Feynman to Geneva for the September 1958 Atoms for Peace Conference.

He served an important role as a member of the Presidential Rogers Commission set up to investigate the cause of the explosion on the space shuttle Challenger on the 28 January 1986. (On 28 January 1986 NASA's space shuttle Challenger broke apart 73 seconds into its flight, killing all seven crew members.) It was a very difficult time for Feynman since throughout the investigation his health was deteriorating. He explained that the cause of the disaster was that the booster rocket's rubber seal could not withstand on the freezing morning of *Challenger*'s launch. He added his own appendix to the commission's report, emphasizing the space agency's failures of risk management.

Contributions

Several achievements of Feynman are crucial for the development of modern physics, some of which are mentioned here. First, and most important, is his work in quantum electrodynamics, the theory that explains the interactions between electromagnetic radiation (photons) and charged subatomic particles such as electrons and positrons (antielectrons) and thus altered the way science understands the nature of waves and particles. For this contribution he was awarded the Nobel Prize for Physics in 1965 jointly with American Physicist Julian Schwinger and Tomonaga Shin'ichirô of Japan. The latter two had independently created equivalent theories, but it was Feynman's that proved the most original and far-reaching.Second, he developed a widely used pictorial representation scheme, later known as Feynman diagrams, for the mathematical expressions describing the behavior of subatomic particles. This work greatly simplified some of the calculations used to observe and predict such interactions and was found useful in many areas of theoretical physics in the second half of the 20th century. Third, Feynman provided a quantum-mechanical explanation for Lev Landau's theory of superfluidity, i.e., the strange, frictionless behaviour of supercooled liquid helium[13]. Applying the Schrödinger equation he showed that the superfluid was displaying quantum mechanical behavior observable on a macroscopic scale. He also attempted to solve the problem of superconductivity, but the solution eluded Feynman[14]. It was solved byJohn Bardeen, Leon Neil Cooper, and John

Robert Schrieffer in 1957 (the BCS theory of superconductivity). Fourth, in 1958 Feynman and Murray Gell-Mann devised a model that accounted for most of the phenomena associated with the weak force, which is the force at work in radioactive decay. This model is very important in particle physics. Fifth, his work on particle spin and the theory of partons" (hypothetical hard particles inside the nucleus of the atom) regarding the strong interactions governing nucleon scattering, which led to the current theory of quarks and were fundamental in pushing forward the modern understanding of particle physics. In 1977 he predicted the existence of sixth quark after the discovery of fifth quark. It was discovered ten years after his death[15,16]. Sixth, he worked on all four of the forces of nature: electromagnetic, the weak force, the strong force and gravity. According to John and Mary Gribbin, "Nobody else has made such influential contributions to the investigation of all four of the interactions"[17].Seventh, he proposed for quantum computation[18]. Eight, he introduced the concept of nanotechnology.

Not only as a researcher but as a teacher was he exceptional. At Caltech in Pasadena the students could ask him any question. Feynman often refused to provide solutions, to spur students on intellectually. His lectures have been published as books and articles: 'The Feynman Lectures on Physics' (in three volumes) (1963-65) (which are considered as classic textbooks), 'The Theory of Fundamental Processes' (1961) and 'The Character of Physical Law' (1967). Some of his other remarkable books are: 'Quantum Electrodynamics' (1961), 'QED: The Strange Theory of Light and Matter' (1985), 'Surely You're Joking, Mr. Feynman! Adventures of a Curious Character' (1985) and 'What Do You Care What Other People Think?': Further Adventures of a Curious Character (1988).

Honours

Apart from the Nobel Prize, Feynman received many awards for his work. Some of which are the Albert Einstein Award(1954), Ernest Orlando Lawrence Award (1962), the Oersted Medal (1972), National Medal of Science (1979). He was elected a member of the National Academy of Sciences, American Physical Society, American Association for the Advancement of Science, Royal Society of London.

Personal Life

In his personal life he was an atheist and left minded. He married Arlene Greenbaum, his classmate in school on 29 June 1942 after obtaining his Ph. D. degree. She died in 1945. His second marriage did not last long. His married his third wife, Gweneth Howarth, in 1960. They had a son, Carl, in 1962, and adopted a daughter, Michelle, in 1968. Feynman became ill in 1978 and cancer in kidney was detected. In early 1979 Feynman's health had deteriorated and he had surgery for stomach cancer. This was very successful. However near the end of 1987 cancer was found again in his abdomen. He was again hospitalized on February 3, 1988 and breathed his last on February 15, 1988.

Conclusion

Feynman was a master conjuror of physics but was very modest. Decades before his 1965 Nobel Prize, Feynman was already a legend of the Manhattan Project. Feynman never dressed up his sentences with fancy words and complex phrases. He tried to explain things clearly and with a touch of humor. He lived by a simple rule: "The first principle is that you must not fool yourself, and you are the easiest person to fool." The phrase speaks to Feynman's enduring modesty and acceptance that he was no better than anyone else. His most urgent goal was to learn about the world and as such he did it with astonishing precision and productivity. Feynman's books urge us to explore the world with open-minded inquisitiveness. The essence of his philosophy was to find something that you can do well, and put your heart and soul into it.

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