

J J Thomson – A ‘Thinking’ Experimentalist

This year we are celebrating the centenary of the ‘discovery’ of the electron: the first of the ‘fundamental’ constituents of all matter to be proposed. This, unlike other candidates for fundamental particles say, proton/neutron, has withstood all the tests of elementarity for the last hundred years. Joseph John Thomson (or J J as he was affectionately called) was the ‘Professor of Experimental Physics’ at the Cavendish Laboratory at Cambridge, England in 1897 when he made the discovery. His 1897 experiment determined neither the mass (m) nor the electric charge (e) of the ‘corpuscles’ (as Thomson had named the carriers of negative electricity), but only the ratio e/m . Most interesting was the fact that it was much larger, by about a factor of 1000, than the largest value known then, viz. that for a hydrogen ion. He had further found the value of e/m to be independent of the nature of the gas and the electrodes used in the discharge tubes which he used for measurements. As a matter of fact, Emil Wiechert and Walter Kaufmann in Germany had got very similar results. However, it was only Thomson who concluded, more than the data strictly warranted, that “We have in Cathode rays a matter in a new state in which the subdivision of matter is carried very much further: a state in which all matter.... is of the same kind,... being the substance from which chemical elements are built up.” His mind was prepared for this leap of imagination and daring speculation¹, due to his preoccupation with the issue of atomicity in the theoretical and experimental investigations he had done till then. In other words, his training and experiences upto the point when he performed his 1897 experiment, were crucial for him to be able to ‘discover’ the electron.

J J was born in Manchester in 1856, the son of an antiquarian bookseller. He once took young Joseph to meet the famous physicist Joule, telling him "someday you will be proud to say that you have met that gentleman". It was this kind of influence that gave him the impetus to go in for ‘original research’ (which elicited a comment from his cousin "don't be such a prig Joe."), a rarity in 1870. Even then J J's choice of a career in physics was accidental. He was studying in Owens College (which was to later become Manchester University where Thomson's Nobel Laureate student Ernest Rutherford was to discover the ‘nucleus’ of an atom in 1911), as an interim measure when he was waiting to find a place as an apprentice to an engineer. His father's untimely death meant lack of funds for the apprenticeship. A scholarship made continuation of studies at Owens possible which, incidentally, had an excellent faculty consisting of people like Balfour Stewart, Osborne Reynolds (of Reynolds Number fame) etc. As a matter of fact, away from Cambridge, Manchester was perhaps the only place where such high level education in physics and mathematics would have been possible at that time. He entered Trinity College on a minor scholarship and prepared for a Mathematical Tripos (the Natural Philosophy Tripos having been just introduced had much less possibility of earning a scholarship) where he studied mathematics

¹ In matters scientific he was a bold speculator. He went on to speculate in his Nobel lecture that his ‘corpuscles might reach us from the sun’. However, in matters financial he was reportedly a very shrewd investor.



and its application to theoretical physics. He passed the Mathematical Tripos in 1880 and was the second Wrangler that year. He applied for and got, at first attempt, a Trinity Fellowship in 1881. He then started his research work in theoretical and experimental physics. The notable part of his work during this period was of theoretical nature and won him the Adams Prize in 1882 and election as a Fellow of the Royal Society (FRS) in 1884. His foray into experimental physics, made possible by his training at Owens, under Lord Rayleigh, then the director of the Cavendish Laboratory, was not very significant. In fact after being elected to succeed Lord Rayleigh at the Cavendish in 1884, Thomson felt like a fisherman who had 'hooked a fish too heavy for him'. Here was a man, 27 years in age, elected to be the 'Professor of *Experimental Physics*', without ever having taught even one course on experimental physics and having been more noted for his mathematical and theoretical prowess. Moreover, by his own admission he "was always clumsy with fingers". But, such small problems notwithstanding, this original thinker of great promise completely fulfilled the confidence the selectors had reposed in him and delivered the goods by making Cavendish Laboratory the seat of excellent, frontline research on fundamental issues in physics. He initiated a series of investigations on conduction of electrical discharge through gases and conductivity of gases induced by the then recently discovered, X-rays. In 1897 he 'discovered' the electron and was awarded the Nobel Prize in 1906 for his researches on 'Conduction of electrical discharge through gases'. In 1918 he resigned from the directorship of the Cavendish to make way for new leadership under Ernest Rutherford and moved to Trinity College as its Master, a post to which he had been elected the year before. He held the position till 1940; the last Master to hold the position for life. He received numerous honours, various medals and awards throughout his life.

In addition to his Nobel Prize winning work, the beginnings he made on mass spectroscopy with his student F W Aston (who later went on to win the Nobel Prize) was also very significant. They showed how different kinds of atoms present in the positive rays in the Cathode ray tubes, can be separated using electric and magnetic fields. They established that even light nuclei like Neon had stable isotopes.

He initially believed that the electrons that he had discovered (corpuscles as he continued to call them for a long time) were the sole constituents of matter. Of course that had to be abandoned very fast. But he gave a model of the atom where the positive charges were uniformly distributed with the electrons sitting like 'plums' in a pudding, the famous plum pudding model of an atom. He used his considerable mathematical expertise, demonstrated in his Adams Prize winning work, to develop a mathematical formulation of this model which was finally disproved by the experiments done by E Rutherford. However, this work is important for the method it displayed.

Apart from his own enormously important contributions to the world of physics and our understanding of matter (indeed his investigations and conclusions about electrons can well be considered to be a watershed) his achievement in establishing a highly successful experimental school is very very significant. He seems to have been like a gardener who nourishes the blossoms and brings out the best



in them. Seven of his 'research assistants' went on to get Nobel Prizes. One of them was his son G P Thomson who got it for demonstrating that the electron was a wave.² A large number were elected as FRS's and many of them held professorships at a large number of prestigious universities. This had to do with his extremely generous personality, his very active imagination and readiness to share the fruits of this imagination, his kindly interest in the activity of his research students and his genuine happiness at their success. He had an extremely open approach to science and welcomed international collaboration in research. As a matter of fact, the Cavendish Laboratory can trace the roots of its 'prosperity' to the 1895 decision of throwing its doors open to researchers from across the world, without requiring a B.A. from Cambridge. Thomson had no part in that decision but his fame attracted the best minds in physics and his uncanny scientific leadership did the rest. A visitor from US once said "... there is a (almost paradoxical) combination of qualities ... (Cavendish) is obviously dominated by J J and yet I have never seen a Laboratory where there seemed to be so much independence and so little restraint on the man with ideas..."

Although J J himself was clumsy with his fingers, to the extent that a research assistant recalls it being necessary not to encourage him to handle the instruments, he had a remarkable, almost intuitive, understanding of an experiment and the apparatus being used. He displayed a genius in diagnosing ills of an apparatus which was not functioning, even without handling it. J J as an experimenter was not the sort to strive for extreme precision but rather he looked for experiments which would confirm or disprove ideas he had about physical reality. It is said that he often left the second decimal place for others to determine.

He was a great pedagogue and laid great value on teaching. In his own words, "there is no better way of getting a good grasp of your subject ... than teaching it or lecturing about it, especially if your hearers know very little about it". He interested himself in improvement in science education at school and university levels. His treatise *Recent researches on Electricity and Magnetism* written in 1893 and the four text books he wrote with H Poynting, helped a lot of young physics students in their training.

He comes across as an extremely humane and urbane person in his autobiography. According to one of his assistants "not only did he show interest in one's scientific work, but he also showed human interest in the man himself, his friends and the institutions with which he was connected". In his son's words 'he was aware of the overriding importance of intangible things, family love, friendships, kindness and sincere religion. This awareness.... made him remarkable as a man as well as a physicist'.

² I could find four such pairs of parent and offspring winning Nobel Prizes in Physical Sciences. Apart from the Thomsons they are W L Bragg and W H Bragg, Mme M Curie and Irene Joliot-Curie and N Bohr and A Bohr. The Braggs are the only ones to have won it jointly.

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