John Canton FRS (1718–72)

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John Canton is known mainly for his work in electrostatics but, as this article shows, he carried out important work in many other branches of physics, including making magnets and demonstrating the compressibility of water.

John Canton (figure 1), the son of a Stroud broadloom weaver, rose by sheer ability and determination to become a Fellow of the Royal Society, a member of its Council, and was twice awarded the coveted Copley Medal of the Society. He was described by Joseph Priestley as one of the 'four most eminent electricians' of the period and he became one of the most respected physicists of his generation, a close friend of, and correspondent with, such figures as Benjamin Franklin, Joseph Priestley and Henry Cavendish.

Yet despite the tributes and recognition of his contemporaries, Canton has remained a largely unknown and forgotten figure in the history of science. Recently, however, there have been indications that Canton's work has at last been given its due recognition; in 1994 the Education Department of The Institute of Physics made a grant to the Friends of Stroud District Museum towards the production of a kit of experiments related to Canton's work in electricity and magnetism for loan to local schools, and in May 1997 a blue plaque was unveiled by Professor Ian Butterworth, then Vice-President of the Institute, on the building in Stroud known as the Old Town Hall, which in the eighteenth century contained the charity school that was attended by the young John.

Canton's parents were dissenters: he was baptized at the nearby non-conformist chapel, and

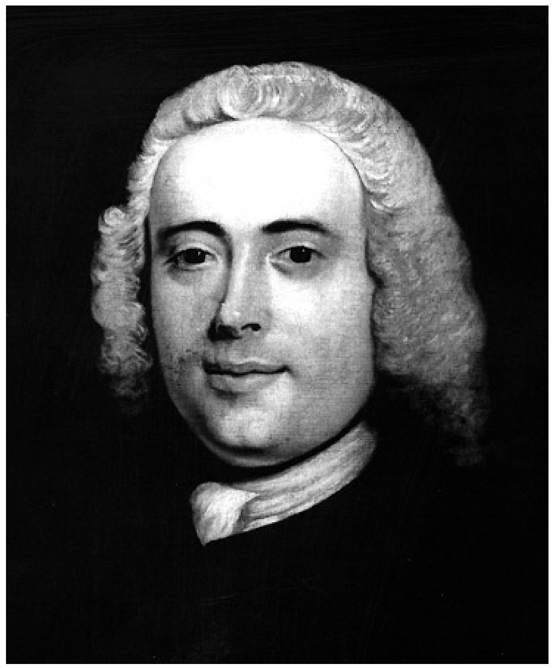

Figure 1. Portrait of John Canton, by an unknown artist, in the National Portrait Gallery, London.

remained a committed member of the dissenting community all his life. At school, he quickly distinguished himself by his academic prowess, particularly in mathematics. When aged about nine, his father decided that the boy had received sufficient education for a future weaver, removed him from school and took him as his apprentice. But the boy was not to be so easily deterred; he took every opportunity to continue his studies, working so late into the night that his father feared for his son's health. During this time he calculated and carved in stone a sundial, which, in addition to the time of day, provided other astronomical information such as time of sunrise, and the position of the sun in the ecliptic. The calculation of the angles for the hour lines necessitated a knowledge of the latitude, and this the boy duly measured, becoming the first person to determine the latitude of Stroud!

The consequences of this for his future could hardly have been greater: his father proudly displayed the dial in front of his cottage, where it attracted the attention of passing gentry, some of whom encouraged John in his studies and permitted him the use of their libraries. One of these was the Rev. Dr Henry Miles, a native of Stroud, but then the minister of a dissenting chapel in Tooting. When the boy was about 18, Miles persuaded Canton senior that his son's abilities were being wasted in Stroud, and the father agreed that young John should accompany Miles to the capital, and stay with him while he sought suitable employment. Accordingly, Canton stayed with Miles for three months, after which he became an articled clerk (i.e. pupil teacher) to the Master of the Academy in Spital Square.

The Spital Academy seems to have been a school for the sons of wealthy Nonconformists, although pupils from other backgrounds also attended. So impressed was the Master with his young assistant that, on completion of the five years' articles, he took Canton into partnership. On Christmas Day 1744, Canton married Penelope Colebrooke, a member of the wealthy banking family, and his climb up the social ladder was crowned the following year when, aged 27, he became Master of the Academy, a position he was to hold for the remainder of his life [1].

Shortly after arriving in London, Miles, who became a FRS in 1743, was able to introduce Canton to the scientific circles in which he moved, and so for the first time Canton was able to meet and socialize with people having similar interests and abilities, and he soon began to devote his leisure time to experimental investigations. Miles owned a collection of 'philosophical instruments', and no doubt Canton had the use of these, which were bequeathed to him on Miles' death.

The Royal Society

By the late 1740s, Canton had achieved a considerable reputation as a skilled experimenter, and in 1749 he was elected a Fellow of the Royal Society, his sponsors including the Astronomer Royal James Bradley, Benjamin Robins, the ballistics expert, and Gowin Knight first librarian of the British Museum, and experimenter in magnetism. Knight had devised a method of making strong magnets, which he kept secret, only divulged after his death, since he was making a considerable sum of money supplying compass needles to the Admiralty. During the 1740s, Canton had also found a method of making strong magnets, but had not disclosed it for fear it might prove injurious to Knight's business. He did, however, demonstrate the method to his friends, who urged him to publicize it. It should be remembered that the only way of making strong magnets at the time was by the use of a lodestone, which was not required in Canton's method. Accordingly, in 1751, with some nervousness and trepidation, Canton demonstrated his method to the Royal Society, and it was subsequently published in *Philosophical Transactions* [2].

Four bars of soft steel were magnetized by stroking them against an iron poker which had become magnetized by being left in its customary position, which happened to coincide approximately with the direction of the Earth's field (see figure 2). Two unmagnetized steel bars were placed between two short bars of iron, so as to form a rectangle. The magnetized bars were then placed in pairs and used to stroke the unmagnetized bars. By a complicated sequence of interchanging the bars, and then using these to magnetize similar ones of hard steel, Canton was able to produce what were, for the time, very strong magnets. The demonstration was a great success, and Canton was awarded the Copley Medal of the Society, which at this period was awarded for the best experiment demonstrated during the year.

Unfortunately, the demonstration provoked a bitter controversy which troubled Canton for the remainder of his life. The Rev. John Michell had, early in 1750, published 'A Treatise on Artificial Magnets', in which he described a method of making strong magnets which was very similar to that of Canton, and he accused the latter of plagiarism. The Royal Society investigated, and found in favour of Canton, and this was supported by the overwhelming opinion of the scientific community in London.

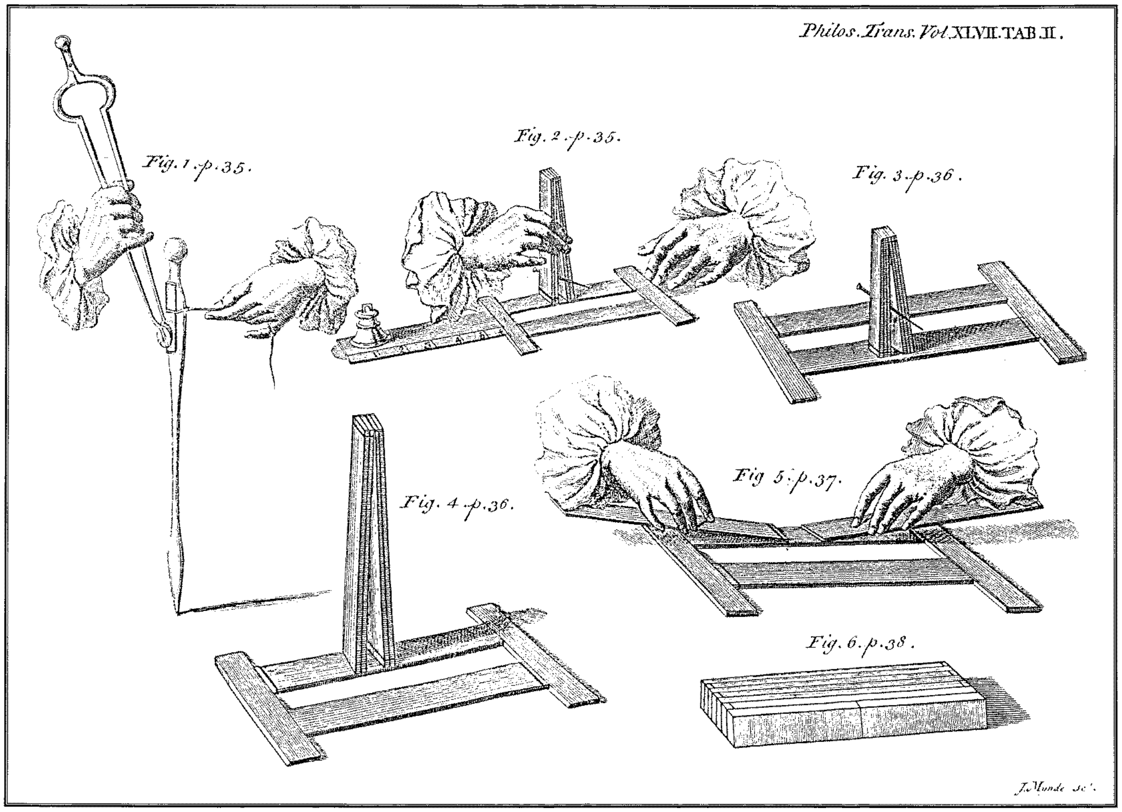

Figure 2. Canton's method of making strong magnets (from *Philosophical Transactions* **47**).

Electrostatics

Canton's reputation today rests mainly on his work in electrostatics. In 1753 and 1754 he published two papers in *Philosophical Transactions* [3, 4] describing the results of his investigations into electrostatic induction. Canton was the inventor of the 'pith ball electroscope', an apparatus invariably found in school and college physics laboratories until quite recently—some are still, no doubt, gathering dust in the cupboards of older establishments! Two small balls of elder pith or cork were suspended from a common support by threads of linen or silk. These would diverge when charged or in the neighbourhood of a charged body. Using this simple apparatus, Canton investigated the charges induced in the balls, and in tin tubes, when electrified glass tubes and sealing wax were brought close to them. These experiments and observations provided a body of empirical knowledge which contributed to the experimental base on which subsequent theoretical developments were founded. The experiments were refined and developed by Franklin and Aepinus. Joseph Priestley, in his *History and Present State of Electricity* [5] wrote:

> 'I shall present ... the finest series of experiments that the whole history of electricity can exhibit, and in which we shall see the genius and address of four of the most eminent electricians in this whole period; namely, Mr Canton and Dr Franklin, Englishmen, and Messrs Wilke and Aepinus, foreigners. Mr Canton had the honour to take the lead, and made all the essential experiments.'

Canton also made the significant discovery that the sign of the charge acquired by a body when electrified by friction depended on the state of its surface and not just the material from which it was composed, as had formerly been believed. For example, a polished glass rod becomes positively charged when rubbed with silk, whereas roughened glass becomes negatively charged.

Thunderstorms

Closely linked with his work on electrostatics, Canton also made important contributions in the field of atmospheric electricity. Although the idea that thunderstorms were electrical in nature had been suggested by many, there was no direct evidence in support of the theory until Benjamin Franklin suggested setting up vertical iron rods, pointed at the upper end and terminating at the lower end in an insulated stand protected from the weather by a kind of 'sentry box'. Franklin believed that, if thunderstorms were electrical, sparks should be obtainable from the lower end of the rod. The experiment was first performed at Marly, near Paris, in May 1752. Franklin's prediction was indeed correct: sparks were obtained from the rod, thus confirming the electrical nature of thunderstorms.

In July of the same year, Franklin performed his famous experiment with the kite. The Marly experiment was soon repeated at several places on the continent, but attempts in Britain met with failure, until Canton, working independently, and with an apparatus substantially different from Franklin's, succeeded in obtaining electricity from thunderstorms on 20 July 1752. Canton described his experiment in a letter to William Watson, subsequently published in *Philosophical Transactions* [6]:

> '... a tin tube, between three and four feet in length, (was) fixed to the top of a glass one, of about eighteen inches. To the upper end of the tin tube, which was not so high as a stack of chimnies on the same house, I fastened three needles with some wire; and to the lower end was solder'd a tin cover to keep the rain from the glass tube, which was set upright in a block of wood...'

Canton found that when he applied his knuckle to the edge of the tin cover during a thunderstorm (figure 3), sparks were obtained. The reason why Canton succeeded whilst others failed was apparently because his apparatus was the only one in which the insulation was protected from the short-circuiting effect of rain.

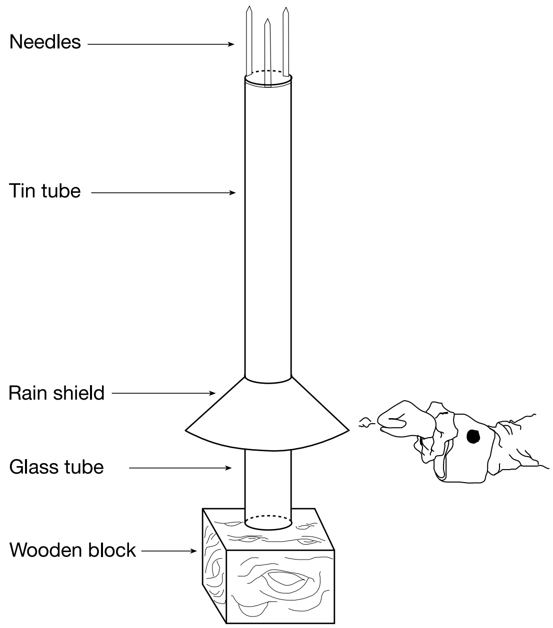

Figure 3. Canton's apparatus for obtaining electricity from thunderclouds (diagram based on his description).

By using a portable version of his pith ball electroscope, in which the balls and thread were contained in a sliding box with a wooden cover (see figure 4), Canton investigated the electrification of clouds, and found that the clouds were sometimes in a positive state and sometimes in a negative state. Franklin had made the same discovery in Philadelphia shortly before (although this was unknown to Canton at the time). Franklin had been greatly surprised by the discovery, and was delighted to hear of its confirmation.

Compressibility of water

Canton's second Copley Medal, awarded in 1765, was for his demonstration of the compressibility of water. In his paper [7] Canton refers to the 'famous Florentine experiment' which had led to the general belief that water was incompressible. The experiment he was referring to was conducted by the '*Academia del Cimento*' of Florence. The Academy only existed for ten years, and its report, published in English translation in 1684, describes three experiments to detect the compressibilty of water, none of which was successful.

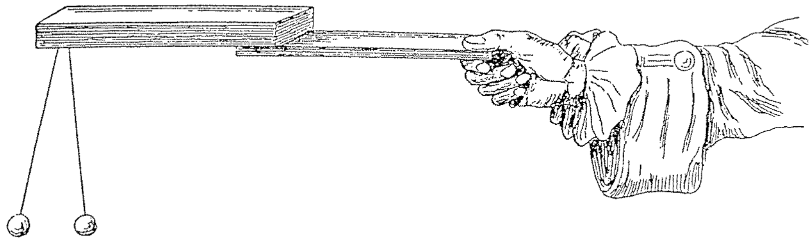

Figure 4. Portable version of Canton's pith ball electroscope (from *Philosophical Transactions* **48.1**).

Canton performed two experiments to detect the compressibility: one qualitative, one quantitative. In the latter experiment, he used a hollow glass sphere 1.6″ (40 mm) in diameter, to which was attached a calibrated capillary tube with 0.01″ internal diameter, open at its end. The sphere and capillary were filled with air-free water, so that the water level was part of the way up the capillary. The apparatus was placed under the receiver of a pump, the air pressure reduced and the water was observed to rise up the capillary. The pressure was then increased above atmospheric pressure, and the water level was depressed. Canton performed several subsidiary experiments to establish that the change in level was not due to distortion of the glass or to the presence of air in the water, and he ensured that temperature remained constant by placing the sphere and tube in a water bath. He argued that the change in volume could only be due to the compressibility of the water in the sphere.

Canton assumed that the pressure was reduced to zero in the first part of the experiment, and increased to two atmospheres in the second part. One may query why, in the first part of the experiment, the water did not boil at reduced pressure. The answer would appear to be that the typical vacuum pump of the mid-eighteenth century was only capable of reducing the pressure to about 1/50 atm at best [8], and so one can assume that the pressure was reduced to about 15 mm Hg (2 kPa). Since the experiment was conducted at 50 °F (10 °C), at which temperature the saturated vapour pressure of water is about 9 mm Hg (1.2 kPa), the water would not have boiled.

Canton concluded that a pressure change of 1 atm results in a change in volume of one part in 10 870. He also measured the compressibility of other liquids, such as spirit of wine, olive oil, mercury and sea water, and found that the compressibility decreased as the density increased.

For these experiments, Canton was nominated for a second Copley Medal in 1764. However, several Fellows were not convinced that the decrease in volume was really due to compressibility, and suspected some spurious effect. The Royal Society therefore appointed a committee of 12 Fellows, chaired by the President, the Earl of Morton, to investigate the matter. After much deliberation, the committee was able to raise no objections, and Canton was awarded the medal.

Had Canton really detected the compressibility of water? Taking his results at their face value, we can calculate a value for the bulk modulus of water, which comes to about 2 GPa. This compares well with the currently accepted value of 2.05 GPa, so we can safely conclude that Canton deserved his medal!

Other investigations

The above represents Canton's major achievements, but in addition he investigated the electrical properties of tourmaline; he discovered the electrical conductivity of molten glass; he kept a daily record of the variation of the Earth's magnetic field and detected its disturbance at the time of the aurora borealis; he made a phosphor from calcined oyster shells and sulphur, known today as 'Canton's Phosphor', and investigated its properties; he participated in the worldwide observations of the transits of Venus in 1761 and 1769; and, by a classic demonstration of scientific method, he showed that the phosphorescence of sea water was due to the decomposition of organic matter, a question that had been in dispute since antiquity.

John Canton died on 22 March 1772, aged 54, the entry in *Biographica Brittanica* (1787) commenting:

> 'the close and sedentary life of Mr Canton arising from an unremitted attention to the duties of his profession, and to the prosecution of his philosophical enquiries and experiments, probably contributed to shorten his days.'

The most fitting tribute to Canton comes from Professor Heilbron, in his entry on Canton in the *Dictionary of Scientific Biography*:

> 'Liberal in politics, latitudinarian in religion, devoted to his profession, schoolmaster Canton was one of the most distinguished of the group of self-made, self-educated men who were the best representatives of English physics in the mid-eighteenth century.'

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