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Nicholas Callan—priest, professor and scientist

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Nicholas Joseph Callan (1799–1864) was an Irish priest and professor of natural philosphy at Maynooth Seminary in Southern Ireland. He was a pioneer in the study of electricity, and among the devices that he constructed were batteries, electromagnets and electric motors. The device that he seemed most proud of, however, was the induction coil which he claimed to have invented. This claim was endorsed by Lord Rosse, President of the Royal Society, in 1864 in a letter to Dr Russell, President of Maynooth.

In 1857, at a meeting of the British Association for the Advancement of Science held in Dublin, Callan made his claim in the following words.

'It is now more than twenty years since I discovered the method of making the induction coil, or a coil by which an electric current of enormous intensity may be produced with the aid of a single galvanic cell—a coil which is now to be used for working the Atlantic Telegraph. Mr Faraday was the first who developed the laws of electrical induction; but he did not discover the method of making a coil by which a current of very great intensity may be obtained by means of a very small battery. This was first discovered in Maynooth College in 1836. In the summer of 1837, I sent the late Mr Sturgeon a small coil which he exhibited at a meeting of the Electrical Society in London and from which he gave shocks to several of the members ... This was the first induction coil of great power ever seen outside the College of Maynooth. The first notice of the discovery of the coil is found in a paper of mine published in the *London Philosophical Magazine* for December 1836 . . . In April 1837, I published in Sturgeon's *Annals of Electricity* a description of an instrument which I devised for producing a rapid succession of electrical currents in the coil by rapidly making and breaking communication with the battery ... Thus before April 1837 I had completed the coil as a machine for producing a regular supply of electricity'.

In order to appraise Callan's researches in the field of electricity we shall consider them under various headings, all closely interrelated but not in chronological order since many of them were carried out simultaneously.

Electromagnetism and the induction coils

Magnetism had intrigued man for centuries. With the advent of batteries it was soon discovered that a coil of wire carrying an electric current has an associated magnetic field and that when a current-carrying coil is wound round an iron bar, the bar becomes magnetic. Sturgeon and Faraday constructed powerful electromagnets and so did Callan, who used them to test the power of his batteries. The College Museum at Maynooth houses several of his electromagnets. The great horseshoe magnet stands more than 1.8 m high, weights more than 95 kg and has poles of diameter 63.5 mm. The ironwork was made by the village blacksmith, James Briody, and Callan wound around the poles heavy copper wire of 7 mm diameter insulated by wrapping tape around it. (This was in the late 1820s, long before insulated wire became a commercial commodity.) This huge electromagnet could lift more than 1000 kg when supplied with current from Callan's battery.

Callan's experiments were influenced by those of Henry and Page in America who independently discovered the phenomenon of self-induction. (Charles Grafton Page himself is sometimes credited with the invention of the induction coil around this time.) When the current flowing through a spiral of copper ribbon was interrupted, a shock was felt if the ends of the ribbon were held in the hands. Callan replaced the ribbon used by Henry and Page in their experiments by copper wire and, very importantly, wound the insulated wire on an iron core and obtained shocks of much greater intensity. In his early investigations he tried cores of various shapes and sizes—thick, thin, straight, horseshoe-shaped and square, but not ring-shaped. Thus, while he was in fact working along the same lines as Faraday, he was not imitating him.

In one of his first coils he wound two 61 m lengths of copper wire insulated with tape around a straight

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Rev. Nicholas J Callan 1799–1864

iron bar 2.54 cm in diameter. The wires were joined in series and the current sent through only one coil but the shock was from the full 122 m. Using one of his cells this apparatus gave shocks of great intensity and Callan used it to assess the power of his batteries. He persuaded his students to take shocks and from their reactions he judged the battery power—a rather original procedure, one must admit! He tells us that with 14 Wollaston cells the shock was so strong that the recipient felt the effect for some days. He adds that with 16 cells nobody could be persuaded to take the shock. There is a story that one student named William Walsh—later Archbishop of Dublin—became unconscious from a shock.

Callan was the first to recognise that the intensity of the shock depended on the rapidity of the break in the primary current. He constructed an ingenious device for interrupting the primary current extremely rapidly. It consisted of the escapement mechanism of a grandfather clock. He attached a crank handle to the escapement cogwheel and a thick copper bar to the rocker. This carried three projecting pieces of copper which dipped into mercury cups. On rotating the crank handle he got more than fifty interruptions per second. He called this device a 'repeater' and published an account of it in Sturgeon's *Annals of Electricity* in April 1837. The repeater is still preserved in the College Museum. It is important in the history of the nature of electromagnetic induction because it focused the attention on the significance of rapid change in the magnetic flux.

In his next experiment Callan used a primary coil of 15.24 m of thick copper wire and a secondary coil of 396.24 m of fine iron wire. This allowed him to increase the density of ampere-turns. In preliminary trials he sent the battery current through the primary coil and took the shock from both primary and secondary coils. His next step was to separate the coils. He found that the shock from the secondary was augmented and thus discovered the principle of the step-up transformer of modern high-voltage electricity. Callan now had all the elements of the modern induction coil except the capacitor. This was suggested 17 years later by Fizeau (1853). Callan used amalgamated copper contacts which dipped in and out of mercury covered with a layer of oil to prevent oxidation.

Callan sent a replica of his apparatus to Sturgeon who demonstrated it to members of the Electrical Society in London in August 1837. It certainly appears that Callan's example gave rise to a spate of induction coils from Sturgeon, Nesbit, Joule, Page, Bacchoffner and others. Bacchoffner explicitly acknowledged his debt to Callan in Sturgeon's *Annals* of 1838 and Sturgeon himself adopted Callan's exact specifications for the lengths of his windings.

In another coil the primary consisted of seven parallel sections each 21 m long and a secondary coil of 3050 m of very fine iron wire, all hand-insulated with a mixture of beeswax and guttapercha (rubber). With this formidable apparatus he obtained secondary currents strong enough to ignite the carbons in an arc lamp. No other experimenter at the time got results in any way comparable. Callan investigated various insulating materials and found that a mixture of beeswax and guttapercha gave the best insulation. The proof of its excellence as an insulator is given by the enormous sparks, 0.38 m long, obtained with his giant induction coil in 1837.

Callan now built his 'medium sized' coil—still kept in the College Museum. It has as core a bundle of thin iron wire, a primary coil of thick copper wire of 3.25 mm diameter and insulated with tape. The secondary coil consists of a few kilometres (thought to be about 10 km) of fine iron wire of 0.26 mm diameter insulated with his beeswax–guttapercha mixture. This coil has a diameter of 0.526 m and a thickness of 0.1 m. The diameter of the central opening which holds the primary coil is 0.15 m. The make and break mechanism is that invented by MacGauley of Dublin, a contemporary of Callan. This mechanism is still used in electric bells and induction coils.

The 'giant coil' which followed in 1837 is also kept in the College Museum (figure 1). The core consists of a bundle of iron rods about 1 m long. It carries the primary coil of thick copper wire, insulated with tape. There are three secondary coils similar to that of the medium coil and these coils are said to contain some 46000 m of fine iron wire, all hand insulated with the beeswax–guttapercha mixture. Fleming (1891) states 'When supplied with current from six cells of the

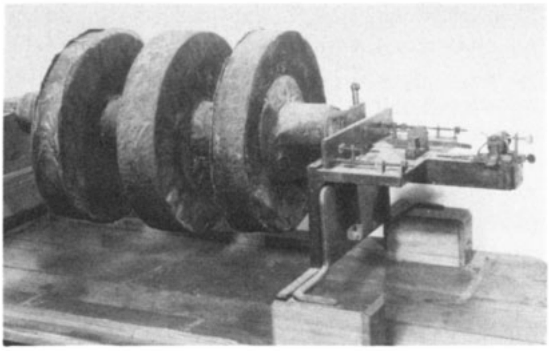

Figure 1 Callan's giant induction coil

Maynooth battery, sparks fifteen inches long can still be obtained'. Prior to 1890 a 15 inch (38 cm) spark was never exceeded. The same Fleming (1893) in volume II of his book *The Alternate Current Transformer in Theory and Practice* devotes several pages to the descriptions and illustrations of various Callan induction coils. In his article on 'The induction coil' in the *Encyclopaedia Britannica* (Fleming 1910) he gives Callan full credit for its invention. Callan sent induction coils to several people besides Sturgeon; he sent them to Lord Rosse, to Downside Abbey, to Dr Fennelly the Bishop of Madras, and to his former professor, Dr Denvir (see inset).

Electric motors

Callan's researches were inspired, one might say, by the motto 'Electricity in the service of man'. He sought to use electricity as a prime mover and to this end he constructed a motor driven by electricity from his batteries. His early motor was very simple in construction and the stator consisted of four pairs of electromagnets attached symmetrically within a metal frame. The rotor was an axle carrying eight arms or spokes with iron plates attached to their ends. The end of the axle carried a small wheel with eight teeth projecting from its rim. As the axle revolved these teeth made and broke contact with a piece of spring metal. Thus a series of pulses of current periodically energised the electromagnets, causing in turn a periodic attraction of the plates which made the axle revolve.

Callan experimented with a number of motors of this type with a view to using an electric engine to pull a train. He hoped to electrify the railway from Dublin to Dunlaoghaire (Kingstown as it was then called). He estimated from the results of his experiments that a magnetic engine as powerful as the steam engine on the Dunlaoghaire line could be built for £250. It would weigh less than two tonnes and could be maintained at an annual cost of under £300—about one-quarter of the cost of steam power. He designed an engine to propel a carriage and load at 8 mph (3.6 $m\,s^{-1}$). He met a number of snags: the batteries were unwieldy and spillable—and hence unsuitable for a moving train. Electromagnetic action is powerful only over short distances: large magnets interfere with one another. He learned that laboratory-scale results do not always apply to large-scale work and in the end he was forced to abandon the idea.

However, his experiments with electric motors were not futile. They led him to the discovery of the principle of the self-induced dynamo. One day while spinning the rotor by hand he was astonished to find that he obtained sparks from the wires leading to the terminals even though the motor was not connected to any battery. This observation is of first importance, and had he followed it up Callan would have added to his laurels the invention of the self-induced dynamo. Such recognition of his discovery would have anticipated that of Werner Siemens by 29 years. Callan noted that the current which produced the sparks was very feeble. This fact probably prevented him from following up his discovery, for at the time he was interested in big currents. Callan's communication of this event is dated 'Maynooth, 20 February 1838'.

Callan relied on his batteries to produce heavy currents at low voltages and on his induction coil to give currents at very high voltages. To measure the large currents from his batteries he used, as we have already seen, the lifting power of electromagnets and also the heating effects produced. He also devised a special type of tangent galvanometer which was afterwards much used by Stewart and Gee and, indeed, sometimes called by their names.

Voltaic cells

W H Wollaston invented the cell which bears his name in 1811. Callan improved this cell by using copper containers which not only acted as positive plates but also eliminated the use of glass or porcelain vessels. In his paper 'On a new galvanic battery' (Callan 1836) he described a very large battery consisting of 20 square zinc plates each 0.6 m × 0.6 m and covered with woven hemp nets to prevent contact with the copper. These plates had to be lowered and raised by means of a windlass and nearly 140 l of acid were required to charge the battery. He devised a system of thick wooden boards with recessed mercury troughs by which he could combine the 20 cells to form one or more cells. To us this appears a cumbersome apparatus but in Callan's day switches were not yet made. He states (Callan 1836) that 'So enormous is the quantity of electricity circulated by the battery (when all cells are in

Nicholas Joseph Callan (1799–1864)

Nicholas Joseph Callan was born on 22 December 1799 at Darver, between Drogheda and Dundalk, Co. Louth. The Callans were a well to do family of considerable local reputation who, in addition to farming extensively, were bakers, maltsters, brewers and distillers.

The fifth son of a family of seven, Callan's early education took place at the Dundalk Academy and from there he was sent to the Navan Seminary in initial preparation for the priesthood. In 1816 he entered the National Seminary at Maynooth, matriculating into the class of rhetoric where he read advanced courses in Latin, Greek and English. In his third year he read natural and experimental philosophy under Dr Cornelius Denvir, later to become Bishop of Down and Connor. Denvir was the first to introduce experimental method into his teaching. He was also interested in electricity and magnetism and his influence largely determined Callan's future researches.

After three years of literary and scientific studies, Callan entered the divinity school and spent a further three years reading dogmatic and moral theology, sacred scripture, Hebrew and canon law. In 1822 he was elected to a studentship on the Dunboyne Establishment which had been set up to enable the more distinguished students to engage in higher studies. He was ordained priest in 1823 and the following year was sent to Rome where he studied at Sapienza University and on 13 April 1826 obtained a doctorate in divinity. During his stay in Rome he became well acquainted with the work of Galvani and Volta.

On the resignation of his former professor Dr Denvir, Callan was appointed in 1826 to the chair of natural philosophy. With characteristic ardour the new professor embarked on his task of teaching mathematics, astronomy and physics. For texts he used Darré's *Treatises on Geometry and Trigonometry* which he completely revised and amplified. He incorporated these into his own *Praelectiones.* Part one deals with conic sections, mechanics, the laws of motion, various mechanical devices such as the lever, the inclined plane and pulley systems. His treatment of optics deals chiefly with mirrors, lenses and telescopes. The second part is a clear introduction to astronomy. Like Newton himself in his *Principia,* Callan employs a good deal of the Euclidean style of definition and demonstration. He provides his student with problems, such as to find the sun's altitude at a stated hour and season; given latitude and the sun's declination, to find when twilight begins; to find the time of the shortest twilight; to find latitude and longitude at sea, and so forth.

He sets down the principles of sun dial construction very clearly and shows how to fix up a dial, vertically or horizontally, so that it indicates correctly the solar time. He devotes considerable attention to the equation of time, the length of the year, the precession of the equinoxes, parallax and refraction. He makes use of the orrery to illustrate features relating to the moon and sun. He employs a 3.5 inch (8.9 cm) refractor telescope by Yeates of Dublin, so that students may see Jupiter's moons 'more clearly than ever Galileo saw them'. A special section of his *Praelectiones* is devoted to the 'Systems of the World' from the Ptolemaic to the Copernican, the merits and demerits of each being argued out; Kepler's laws and the work of Tycho Brahe come in for particular study to enable the student to find the synodic time of a planet and calculate its mean motion.

This 'gentleman's course' inaugurated and developed by Callan remained an integral part of the Maynooth curriculum until 1910 when the college came under the National University of Ireland.

From his *Praelectiones* we also gather that Callan was highly sensitive to the words of the psalmist: '*Caeli ennarant gloriam Dei, et opus manuum ejus annuntiat firmamentum*'—'The skies declare the glory of God and the vault of heaven proclaims his craftsmanship'. As a priest–scientist, Callan would be sympathetic to the view that, of all disciplines, science brings us nearest to the contemplation of the infinite, and so awakens in us a cosmic consciousness that somehow borders on religious experience.

Callan's scientific publications

1836 Sturgeon's *Annals of Electricity* **1** The Callan repeater (interruptor) 229–30; 'Electromagnets for magnetic and electric purposes' 295–302; 'Electromagnet of great power' 376–9; on connecting electromagnets 491–4

1836 *Phil. Mag.* **9** 272–8 Results of several years' experiments with electromagnets and transformers

1837 *Phil. Mag.* **10** 459 Reply to Ritchie's criticism

1838 Sturgeon's *Annals of Electricity* **2** 317–8 Priority of the Callan coil; the self-induced dynamo

1840 Sturgeon's *Annals of Electricity* **4** 333–4 Priority of Callan's electromagnetic engines

1847 *Proc. R. Irish. Acad.* **3** 471–6 New battery and experiments

1848 *Phil. Mag.* **33** 49–53 A new prodigious battery

1850 *Proc. R. Irish Acad.* **4** 152–7 Improved battery and experiments

1854 *Phil. Mag.* **7** 73–97 Illumination by Maynooth battery; galvanometers for large currents

1855 *Proc. R. Irish Acad.* **6** Illumination by the iron battery (title only)

1855 *Phil. Mag.* **9** 260–72 Single-fluid cell for illumination

1857 *Rept Brit. Assoc. Adv. Sci.* part 2 11–3 Improved induction coil

1857 *Phil. Mag.* **14** 323–40 The induction apparatus; high tension insulation

1858 *Phil. Mag.* **15** 255–9 Contact breakers and condensers

1859 *Phil. Mag.* **17** 332–4 Electrodynamic induction

1863 *Phil. Mag.* **25** 413–7 Callan's great coil: sparking potentials; the Callan point-plate valve

series–parallel combination), that on one occasion after having been active for more than an hour it rendered powerfully magnetic an electromagnet; platinum wire 1/30th inch (0.85 mm) thick was rapidly melted; and that copper and iron wires 1/12th inch (2.1 mm) thick were deflagrated in a most brilliant manner'.

Callan now experimented with the Poggendorff

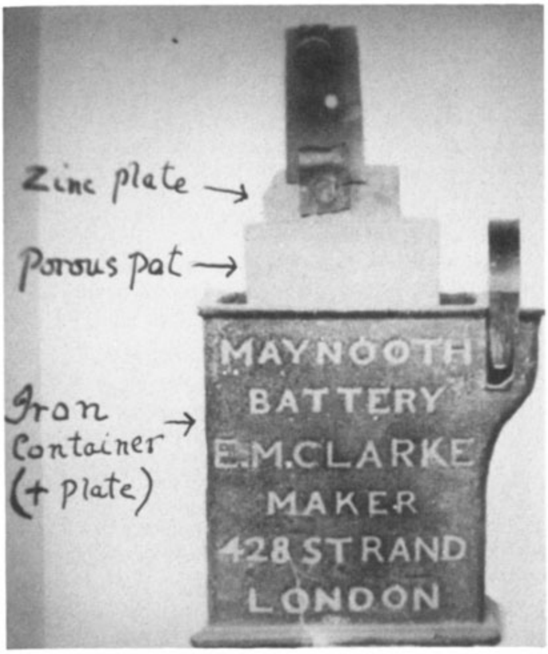

Figure 2 Callan's iron–zinc cell

dichromate cell and the Daniell cell. The former was rather wasteful of zinc and the latter had too high an internal resistance to give heavy currents. He next tried Grove's cell but platinum was far too expensive, even in those days. He next worked with the Bunsen cell in which carbon plates were used instead of platinum, but found it gave off very disagreeable fumes of nitrogen peroxide. Difficulties also arose in making good contact between the copper wires and the carbon.

In the College Museum there are some large carbon–zinc cells in glass containers. The zinc plates are cylindrical in shape, being about 0.63 m high and 0.24 m in diameter. The carbon poles are slightly taller and have a diameter of about 0.14 m. On analysing the incrustation on a zinc plate, I found it to contain ammonium chloride. This indicates that Callan used sal ammoniac as an electrolyte—the cell was in fact an original version of the Leclanché cell.

Callan now tried lead plates, lead plates coated with platinum black, and gilt lead plates—always of course in combination with zinc plates—and found them to give satisfactory results. He went on to try various other metals, all of which were inferior to platinum or platinised lead, with the exception of iron.

In 1846 he published a paper entitled 'On a new voltaic battery, cheap in its construction and use and more powerful than any battery yet made; and a cheap substitute for the nitric acid of Grove's platinum battery' (Callan 1847). In it he describes his cast iron cell. It was a cast iron container in which stood a thin-walled porous pot with the zinc plate standing in dilute sulphuric acid. The iron container held a mixture of sulphuric acid and nitre—a mixture which he found to be just as effective as nitric acid and much cheaper.

Callan now applied to the Trustees of the College for permission to convert the big Wollaston battery into a cast iron one. Using the zinc plates of the former he constructed 577 cells. This was reckoned to be the world's largest battery. It was at least twice as powerful as the Wollaston battery constructed on Napoleon's orders for the Ecole Polytechnique in Paris. On 7 March 1848 Callan demonstrated the power of his new battery before a large audience in the College. A large turkey placed in circuit was instantly electrocuted. An arc of blinding light of some 13 cm length was obtained between brass and copper terminals; carbon rods burned away too quickly for the length of the arc to be accurately determined. At this stage some of the copper leads fell off the zinc plates as the solder melted.

From these experiments and others Callan concluded that the cast iron cell was several times as powerful as the Wollaston cell of the same size and twice as powerful as the Grove's cell. Subsequently the cast iron cell was manufactured commercially by E M Clarke at the Adelaide Gallery of Practical Science, 428 The Strand, London (figure 2).

Callan had already found that cast iron withstood the action of nitric acid almost as well as platinum or gold. He made the further discovery that cast iron treated with nitric acid became 'passive' and resistant to weathering and patented the process. The College Museum still has the elaborately worded document conferring the patent rights. Attached to this is the Seal of Queen Victoria, a large cylindrical block of yellow sealing wax embossed with the Royal Seal and enclosed in a tin box.

Callan also experimented with electric lighting, that is to say arc lighting and limelight. By electrolysing acidulated water he got hydrogen and oxygen which game him some kind of oxy-hydrogen torch which heated up a lump of lime so that it gave out a brilliant light. This, he hoped, would serve for lighthouse beacons. Practical difficulties, however, militated against its use: hydrogen and oxygen form a highly explosive gas when mixed. Excessive work led to a breakdown in health entailing an interruption of his scientific studies and forcing him to take a long rest for the greater part of 1849 to 1851.

Callan died on 10 January 1864. His obituary in the *Dundalk Democrat* (17 January) stated:

'His extraordinary piety, his perfect simplicity and unaffected candour endeared him to everyone who knew him. For many years he was regarded by both professors and students of Maynooth with a

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judged by university results. I would have expected girls who are capable of performing well in school physics to be more likely to continue in physics than their peers. It may be that the university has a socialising effect on the students such that students pace themselves with their peers and achieve only what is necessary to keep pace and retain their place in the peer group, thus producing lower mean marks than expected for exceptionally good subgroups. On the other hand, one might assume that the university system ranks and grades students correctly and one can then ask where the other potentially good women physics students go, or whether they even exist.

It is commonplace to say that we are throwing away half our potential physicists (Swarbrick 1981) through 'discrimination' (Deeson 1981). This is a serious and worrying problem but perhaps we should ask ourselves whether or not we are being realistic in assuming that the other half indeed exists in the form of available adequate physics students. If the women we find in universities are *not* more highly selected than the men, as studies of the women's scores suggest, then perhaps already we are attracting roughly the same proportion of the potentially good women physicists as of the men. Physics has a male image (Kelly 1981b) and nature, developed by males over the centuries. Perhaps it is unreasonable to expect all women to perform well in 'physics-male' and we should rather be asking our women to develop a related subject of 'physics-female' whose development techniques and bias reflect the abilities and interests of women.

It is possible that only 10% of women may wish to take physics after the obstacles of the secondary school system. The selection of these girls must however be rather random in terms of their ability to cope with university physics; otherwise the mean results presented above would not so closely match women and men. The suggestion here is that we should give serious consideration to the possibility that only 10% of our women can compete successfully with the men in our present subject, 'physics-male', and that in a similar way there may be a different but equally interesting, valid and useful subject, 'physics-female', which is better suited to all women and useful for only a small fraction of the men.

The bias of schools may be right; the physics discipline as we now know it may not be suitable for the majority of women. It may not be our attitudes to teaching that need revision, but that new developments need to be made in the discipline itself, led by women, which will lead to the subject becoming more balanced. The pointers may be there already. Look at astronomy compared to physics. Why is this subject less sexist? What properties in our physics courses show less sexual imbalance? Perhaps we can aim to produce a sexually balanced subject rather than trying to convert our potential students away from their existing gender.

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reverence and affection that could hardly be understood by those who did not witness his daily life; and they all deplore his death as an irreparable loss to the College which he at once edified by his virtues and adorned by his learning'.

However, were it not for the painstaking researches of the late Right Reverend Monsignor McLaughlin—himself a successor to Callan in the chair of natural philosophy and experimental physics and vice-president of Maynooth College—Callan's researches and discoveries could have disappeared entirely into oblivion. Maynooth College, and indeed the world of science, is indebted to Monsignor McLaughlin for putting Callan into true perspective and for preserving his name and fame for future historians of science.

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