JAMES CLERK MAXWELL FOUNDATION

14 India Street, Edinburgh, EH3 6EZ
The birthplace in 1831 of James Clerk Maxwell.

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Scottish Charity: SC 015003

Introduction

James Clerk Maxwell as a child.

This house,14 India Street, is the birthplace of James Clerk Maxwell. It was acquired by the Foundation in 1993 having previously been privately owned. The cost of refurbishment was met by grants and loans, some of them conditional on bringing the interior as close as possible to that of the late Georgian era, when the family lived here. James's father, John Clerk Maxwell, had inherited the estate of Glenlair in Galloway in southwest Scotland and divided his time between Glenlair and this town-house. James was born here in Edinburgh on 13 June 1831 and the Clerk Maxwell family moved back to Glenlair permanently when James was two years old.

His mother died when James was only eight years old and, two years later, he returned to Edinburgh to attend school at the Edinburgh Academy staying with his father's sister Isabella Wedderburn (neé Clerk) at her home at 31 Heriot Row, round the corner from India Street. James went on to study at the University of Edinburgh during the years 1847-1850.

Exhibition Room

Glenlair in Maxwell's time, before the 1920's fire

This room, originally the Maxwell's dining room, is one of the best refurbished Georgian rooms in Edinburgh. The décor is characteristically subdued with most of the colour provided by carpet and curtains. The original structure of the room, including cornices, has survived although the chandelier is a recent replacement.

With the exception of Professor Tait, the portraits at eye level are of the family. The one above the fireplace is a copy of an original portrait (of James Clerk Maxwell) by Lowes Dickinson in Trinity College, Cambridge (Maxwell's College). Between it and the window is a portrait of James' father, John Clerk Maxwell. This is again a copy, the original being in the habitable part of the fire-damaged Penicuik House, home of the 'Clerks of Penicuik'. The present (11th) Baronet is Sir Robert Maxwell Clerk.

Moving into the Wedderburn's at 31 Heriot Row, in 1841, to attend school and University

Facing James and John are portraits of Maxwell's uncles, Robert and John, his aunt Jane on his mother's side and his mother Frances Cay; the older girl in the portrait nearest to the door. These portraits were done by their mother, Elizabeth, whose self portrait is between the windows. Facing the windows across the room is the portrait of her husband, Robert Hodshon Cay, Judge of the High Court of Admiralty. This is a copy of the original by the famous Scottish portrait painter Sir Henry Raeburn.

The exception is the portrait to the left of the fireplace, an original of Maxwell's lifelong friend and scientific colleague Peter Guthrie Tait, who was preferred to Maxwell when the chair of Natural Philosophy at The University of Edinburgh was filled in 1860. Maxwell and Tait were both born in 1831 and attended the same school, the Edinburgh Academy (a quarter of a mile down the hill from India Street), but in different years, Maxwell being one year ahead of Tait.

The posters and equipment at the lower level represent some of Maxwell's achievements and developments from them. The narrative begins below Tait, going to the right round the room.

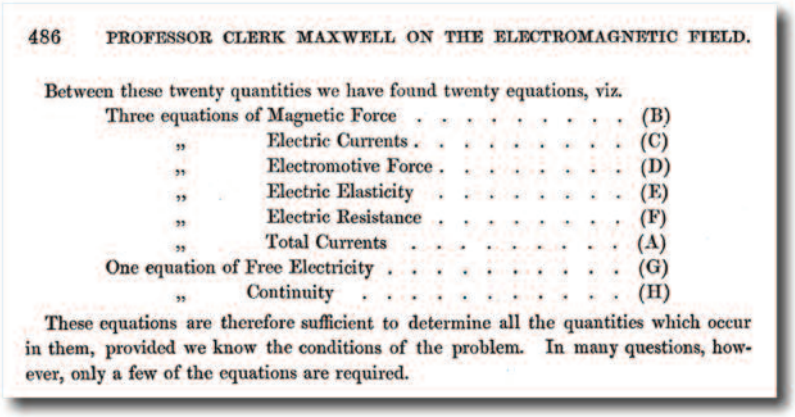
The first is a scene from the laying of an early transatlantic cable, whose construction required best quality copper as measured by the value of its electrical conductivity.

This links to the second, the determination of the unit of electrical resistance, the ohm. The original of the portrait of Maxwell with his resistance apparatus is at the headquarters of the Institution of Engineering and Technology (IET) in London, incorporating the Institution of Electrical Engineers (IEE).

The fireplace is occupied by a poster from a 14 India Street symposium, held soon after the completion of the building restoration. The posters on either side of Maxwell's portrait list Maxwell's achievements and legacy and provide a timeline for the development of radio.

Maxwell's first colour photograph of the 'tartan ribbon'

Finally, there is a poster summarising the first full colour projected image, famously demonstrated by Maxwell in 1861 at the Royal Institution in London. He achieved this by making three black and white photographic plates which were photographed through red, green and blue filters respectively. He then used three magic lanterns to superimpose these three black and white images, each projected through the same red, green and blue filters, to produce the above first colour image of the 'tartan ribbon'.



486 PROFESSOR CLERK MAXWELL ON THE ELECTROMAGNETIC FIELD.

Between these twenty quantities we have found twenty equations, viz.

Three equations of Magnetic Force	. . . . .	(B)
„ Electric Currents	. . . . .	(C)
„ Electromotive Force	. . . . .	(D)
„ Electric Elasticity	. . . . .	(E)
„ Electric Resistance	. . . . .	(F)
„ Total Currents	. . . . .	(A)
One equation of Free Electricity	. . . . .	(G)
„ Continuity	. . . . .	(H)

These equations are therefore sufficient to determine all the quantities which occur in them, provided we know the conditions of the problem. In many questions, however, only a few of the equations are required.

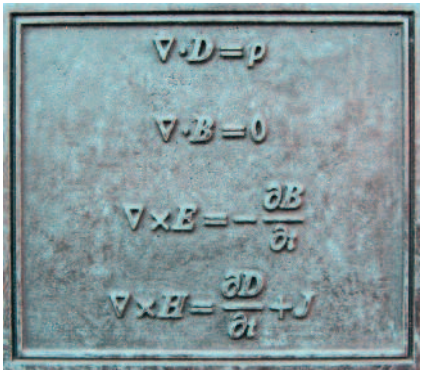
Extract from Maxwell's Phil. Trans. Roy. Soc. London, Vol. CLV, 1865 paper

This major technical achievement, the production of colour images with three colour filters, is widely used today in printing and colour image capture (in digital still and video cameras), in televisions and computer screens. His most significant contribution, as regarded by electrical engineers, was in defining the equations governing electromagnetics ('Maxwell's Equations'), forming the foundation of today's radar, navigation (Global Positioning System, GPS), radio communication, and many other systems.

In his famous 1865 paper, Maxwell defined electromagnetics in terms of 20 equations, of which 13 may be regarded as the basis for the now familiar Heaviside-Lorentz form:

$$\nabla \cdot \mathbf{D} = \rho \qquad \nabla \cdot \mathbf{B} = 0 \qquad \nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \qquad \nabla \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$$

When, in 1873, he published his book *"Treatise on Electricity and Magnetism"*, Maxwell managed to compress his 20 original equations to eight by using the quaternions promoted by his school friend Professor Tait. In doing so he added one more important equation, $\mathfrak{F} = V.\mathfrak{CB} + e\mathfrak{E} - m\nabla\Omega$, which was the precursor of the Lorentz force.

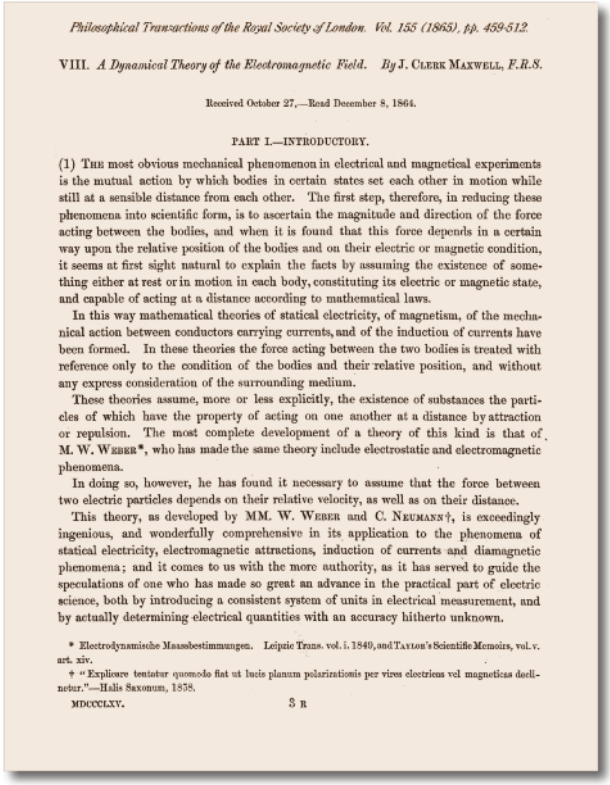


Maxwell's equations, as displayed below his Edinburgh statue.

Maxwell, courtesy of Trinity College Cambridge

While this was a great step forward, quaternions proved to be less than popular. Oliver Heaviside, who was a keen proponent of Maxwell's theory, saw the need to restate the equations and so in 1885, just a few years after Maxwell's death, he developed the now familiar vector form, simplifying some of them in the process. However, this was not quite the end of the story, for in the opening years of the 20th century Lorentz gave the equations a microscopic basis, highlighting the four equations on the statue, together with the Lorentz force, $\mathbf{F}=q(\mathbf{E}+\mathbf{v}\times\mathbf{B})$, as the fundamental equations of electrodynamics. The final touch was due to J. Willard Gibbs, for it is his notation that we generally use today. The publication of his 1902 book on *"Vector Analysis"* eventually led to Heaviside's 'div' and 'curl' being replaced by Gibbs' $\nabla\cdot$ and $\nabla\times$, but in all other respects the four equations we see on the statue are the direct result of Heaviside's tribute to Maxwell.

Next are shown the basics of the design of the Maxwell's apparatus to measure the ratio of electromagnetic to electrostatic units of electrical charge. Maxwell showed mathematically that the numerical value of this ratio was equal to the speed of electromagnetic waves. Maxwell recognised that the speed of electromagnetic waves was also equal to the speed of light. Thus Maxwell stated in his 1865 paper *"…it seems we have strong reason to conclude that light itself (including radiant heat and other radiations if any) is an electromagnetic disturbance in the form of waves propagated… according the electromagnetic laws"*. This was the most stunning conclusion of 19th century theoretical physics.



Philosophical Transactions of the Royal Society of London. Vol. 155 (1865), pp. 459-512.

VIII. *A Dynamical Theory of the Electromagnetic Field.* By J. Clerk Maxwell, *F.R.S.*

Received October 27,—Read December 8, 1864.

PART I.—INTRODUCTORY.

(1) The most obvious mechanical phenomenon in electrical and magnetical experiments is the mutual action by which bodies in certain states set each other in motion while still at a sensible distance from each other. The first step, therefore, in reducing these phenomena into scientific form, is to ascertain the magnitude and direction of the force acting between the bodies, and when it is found that this force depends in a certain way upon the relative position of the bodies and on their electric or magnetic condition, it seems at first sight natural to explain the facts by assuming the existence of something either at rest or in motion in each body, constituting its electric or magnetic state, and capable of acting at a distance according to mathematical laws.

In this way mathematical theories of statical electricity, of magnetism, of the mechanical action between conductors carrying currents, and of the induction of currents have been formed. In these theories the force acting between the two bodies is treated with reference only to the condition of the bodies and their relative position, and without any express consideration of the surrounding medium.

These theories assume, more or less explicitly, the existence of substances the particles of which have the property of acting on one another at a distance by attraction or repulsion. The most complete development of a theory of this kind is that of M. W. Weber*, who has made the same theory include electrostatic and electromagnetic phenomena.

In doing so, however, he has found it necessary to assume that the force between two electric particles depends on their relative velocity, as well as on their distance.

This theory, as developed by MM. W. Weber and C. Neumann†, is exceedingly ingenious, and wonderfully comprehensive in its application to the phenomena of statical electricity, electromagnetic attractions, induction of currents and diamagnetic phenomena; and it comes to us with the more authority, as it has served to guide the speculations of one who has made so great an advance in the practical part of electric science, both by introducing a consistent system of units in electrical measurement, and by actually determining electrical quantities with an accuracy hitherto unknown.

* Electrodynamische Maassbestimmungen. Leipzic Trans. vol. i. 1849, and Taylor's Scientific Memoirs, vol. v. art. xiv.

† "Explicare tentatur quomodo fiat ut lucis planum polarizationis per vires electricas vel magneticas declinetur."—Halis Saxonum, 1858.

MDCCCLXV. 3 R

Maxwell's famous paper (Phil. Trans. Roy. Soc. London, Vol. CLV, 1865)

In front are a slide projector of design not too many years later than Maxwell's 1861 magic lanterns, a replica of part of the balance arm of Maxwell's apparatus to measure the ratio of electrical and magnetic units and a replica of Maxwell's colour box which he used to analyse and synthesise light colours to underpin his observations on colour mixing and colour perception. The replicas were produced in the Cavendish Laboratory, Cambridge.

The display cabinet contains items which are unique or very rare. These include Maxwell's three black and white magic lantern slides, which Maxwell used to make the first colour projection and also his medals. A few pages, on loan from The Edinburgh Academy, display his work on rolling curves on which he based his second scientific paper *"The Theory of Rolling Curves"* written at age 17, while at university.

The copy of his 1865 paper, *"A dynamical theory of the electromagnetic field"*, where marked in the margin, shows his speculation that electromagnetic waves would embrace not just light and radiant heat (i.e. near infra-red light) but "other radiations, if any", pointing to the whole electromagnetic spectrum. It also includes a few lines down the page an acknowledgement to Michael Faraday who first speculated, in 1846, that light was an electromagnetic wave and whose pioneering researches inspired Maxwell. The Faraday theme continues with, on display, the IEE Faraday Medal awarded in 2004 to one of our Trustees, Peter Grant. Professor Tait's school medals, gifted to the Foundation by his great grandson Murray Tait, show that Tait was top of his class (dux) throughout his school career at the Edinburgh Academy.

Moving from the windows to the entrance door, on the opposite wall below Aunt Jane's portrait, are her own paintings of a room in her house close by at 6 Great Stuart Street. The divided room has its partition drawn back and Maxwell is shown sitting at one of Aunt Jane's tables in the actual chair (since re-upholstered in a wave motif) on the floor in front.

Below the paintings is a display of wireless receivers on loan from the Museum of Communication, in Burntisland in Fife. These link to the later poster 'Maxwell to Marconi', see library, which commemorates the centenary of the first cross-channel wireless signal in 1899 followed by the first transatlantic signal in 1901.

Photo montage from Marconi's wireless telegraphy station, Wellfleet, Cape Cod, USA.

The pictures above show the former Marconi installation at Cape Cod, USA. Here Marconi built on the pioneering work of Maxwell to construct his first wireless telegraphy station and, in particular, he designed the important 200 m diameter conical antenna which coupled the transmitter into radio transmissions. In 1903 President Theodore Roosevelt sent his famous Morse coded message to King Edward VII using a 20,000 V condenser-based spark transmitter, powered by a 45 hp generator.

JCM and his cousin Jemima paddling in washtubs on the river Urr

Between the wireless apparatus and the entrance door is a suite of posters telling part of the history of wireless communication at sea. The receivers are displayed on the base of a bookcase gifted by the Cavendish Laboratory together with the writing desk below the Robert Hodshon Cay portrait. Both items had been in the first Cavendish Laboratory, designed by Maxwell when he came out of retirement to return to Cambridge as its first director and Professor of Experimental Physics from 1871 – 1879.

By the entrance door is a poster displaying the complete range of the electromagnetic spectrum and representative applications. The vast range of this spectrum attests to the prescient 1865 comment by Maxwell *"…radiant heat (and other radiations, if any)…"*.

Our sister charity, the Clerk Maxwell Cancer Research Fund, actively supports the use of electromagnetic radiations in the treatment of cancer. Maxwell died from stomach cancer at the early age of 48, his mother died from the same illness and at the same age.

Library

The library, on the ground floor at the back of the house overlooking the garden, has a display of remarkable watercolours by Maxwell's cousin Jemima Wedderburn, daughter of Maxwell's aunt, Isabella, on his father's side. The watercolours, by Jemima while still in her teens, are snapshots of the Clerk Maxwell family life. They include one of Maxwell arriving on 18 November 1841 at 31 Heriot Row prior to starting school, see earlier photo. This was several weeks into term and Maxwell's intended class was full, which is why he was moved to the class above and so never competed at school with Tait, who was (thus) top of his class throughout.

The main paintings displayed in the library are:

- A first family play featuring JCM and the Wedderburn children – around 9 Oct 1843,
- A second family play featuring JCM and the Wedderburn children – around 9 Oct 1843,
- JCM and his father arriving by horse drawn coach at 31 Heriot Row, to stay with the Wedderburn's when returning to Edinburgh to study at The Academy – 18 Nov 1841,
- Wedderburn's arriving at Glenlair by night – 13 Oct 1841,
- JCM and his father at Newton en route to Glenlair – 15 November 1841,
- Drawing of a boat approaching a pier – 11 June 1840,
- People on horseback – possibly JCM leading a horse,
- JCM and his cousin Jemima paddling in washtubs on the river Urr – Sept 1843, see previous page,
- JCM and his father at highland cattle show – 21 August 1842,
- Family picnic on the shore, Roshven, Lochailort, Professor Blackburn's home – 18 Sep 1851.

On the wall opposite the window is an electronic display which provides a slide show of key highlights from Maxwell's life including two Jemima paintings, Maxwell's publications, the coloured tartan ribbon and bonnet, Marconi's US Cape Cod radio transmission station, the restored porch at Glenlair, the Edinburgh statue etc. Below this are two posters the 'Beginnings of Wireless', which chart wireless developments from Maxwell through Marconi on to the start of broadcast in the 1920's, and a second one highlighting the many impacts of Maxwell's work.

Restored porch at Glenlair today

Hall and Staircase

The entrance has been carefully restored with the hall containing three commemorative features. The bust of Maxwell (by Pilkington Jackson) is a copy of the one originally at Marischal College Aberdeen, where Maxwell had his first professorial appointment (1856-1860). Above the settle is the plaque commemorating the opening, in 1993, of 14 India Street as the home of the James Clerk Maxwell Foundation. On the opposite wall is the 'Milestone in Electrical Engineering and Computing' plaque of the American Institute of Electrical and Electronics Engineers (IEEE). This commemorates Maxwell's electromagnetic theory. It is one of three identical plaques, the other two being in the restored entrance porch of Glenlair House, see above and in King's College, London where Maxwell was Professor of Natural Philosophy from 1860 to 1865.

The engravings on the staircase walls are from the Herschel Collection purchased by the Foundation's Founder, Professor Sydney Ross. They sample the history of science and mathematics from Copernicus onwards, arriving at Maxwell's contemporaries Michael Faraday and Lord Kelvin near the landing. There is the painting of Maxwell and his wife Katherine and, inevitably, their dog Toby. Continuing upstairs, sketches and photographs (various donors) include the Maxwellians (G F Fitzgerald, Sir Oliver Lodge and Oliver Heaviside), Heinrich Hertz and, significantly, Albert Einstein.

Statue in George Street, Edinburgh, by the sculptor, Alexander Stoddart

Motorola Room

This was the bedroom where James Clerk Maxwell was born, now a multipurpose reception area for the Drawing Room beyond the partition. Above the fireplace is a portrait of Sydney Ross. To the right of the fireplace is an example of a later work by Jemima, following her marriage to Hugh Blackburn, Professor of Mathematics at Glasgow University.

Lecture Room

This, originally the Drawing Room, is now also multipurpose and used for receptions, seminars and other functions. Echoing the epigram on the plaque in the Hall is a Latin epigram by the late John M Paxton, brother of Trustee Roland Paxton. The translation reads as:

From this house of his birth,
his name is now widespread
– across the entire terrestrial globe
and even to the stars.

The painting by Lucinda Mackay above the fireplace is of a near neighbour, Professor Peter Higgs, whose research led to the ongoing search, in the Large Hadron Collider at CERN in Geneva, for the 'Higgs boson'.

The whiteboards and projection equipment (21st century) were installed by the first tenant, the International Centre for Mathematical Sciences. The Centre was so successful that it outgrew the building and now occupies the former e-Science building in South College Street, adjacent to Edinburgh University's Old College on the edge of the Old Town. The present tenant, occupying the top floor, is the human resources company Gravitate H R.

References

1 Documents on the Foundation's website, see,
http://www.clerkmaxwellfoundation.org/html/html/further_documents.html

2 Mahon B, *"The Man Who Changed Everything: the Life of James Clerk Maxwell"*
John Wiley & Sons, 2003.

3 Tolstoy I, *"James Clerk Maxwell, a Biography"*, Canongate, Edinburgh, 1981.

4 Everitt C W F, *"James Clerk Maxwell, Physicist and Natural Philosopher"*,
Charles Scribner's Sons, NewYork, 1974.

5 Campbell L and Garnett W, *"The Life of James Clerk Maxwell"*, Macmillan, London, 1882.
(James Rautio has put the above complete text on his company's website,
Sonnet Software, see **www.sonnetsoftware.com/bio/maxbio.pdf**

6 The University of Toronto, gives access to the collection of Maxwell's papers
by W D Niven (ed.) "The Scientific Papers of James Clerk Maxwell" Cambridge
University Press 1890:
www.archive.org/details/scientificpapers01maxwuoft
www.archive.org/details/scientificpapers02maxwuoft

7 *"Celebration of Achievements & Legacy of James Clerk Maxwell"*, ISBN: 978 0 902198 852,
Royal Society of Edinburgh 2008, on the occasion of the statue unveiling

All the above books can be found in the James Clerk Maxwell Foundation Library.

Key dates in the life of Maxwell

1831	Born 13 June, 14 India Street
1833	Moved to Glenlair
1841	Enrolled at Edinburgh Academy
1846	Maxwell's first paper *"On the description of oval curves and those having a plurality of foci"*, Proc. Roy. Soc. Edinburgh, Vol. II
1847 – 50	Studied, University of Edinburgh
1850	Entered Peterhouse College, Cambridge - after one term migrated to Trinity College
1854	Mathematical Tripos – 2nd Wrangler and First (Equal) Smith's Prizeman
1856 – 60	Professor of Physics at Marischal College, Aberdeen
1856	Elected Fellow Royal Society Edinburgh (FRSE) aged 24
1857	Essay on "The Stability of Saturn's Rings" won the Adams Prize, University of Cambridge
1858	Married Katherine Mary Dewar, daughter of the Reverend Daniel Dewar, principal of Marischal College, Aberdeen
1860	Paper *"Illustrations of the Dynamical Theory of Gases"*, in which the Maxwell-Bolzmann distribution for molecular velocities in a gas is derived
1860 – 65	Professor at King's College, London
1860	Awarded Rumford Medal, Royal Society
1861	Royal Institution, first demonstration of colour reproduction
1861	Elected Fellow Royal Society (FRS) shortly before his 30th birthday
1861/2	*"On physical lines of force"*, Phil. Mag., Vols. 21 & 23. Calculates that electric and magnetic effects travel at speed of light and states "…we can scarcely avoid the inference that light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena."
1864	*"On reciprocal figures and diagrams of forces"*, Phil. Mag., Vol. 27. First paper showing how to calculate stresses in multi-strut bridge frames. Later effort led to 1869 award of the RSE Keith Medal (see below)
1864	Famous oral presentation: *"Dynamical theory of the electromagnetic field"* to the Royal Society. First appearance of 'Maxwell's Equations' and the assertion that "…it seems we have strong reason to conclude that light itself (including radiant heat and other radiations if any) is an electromagnetic disturbance in the form of waves propagated …according the electromagnetic laws"
1865	Above paper, *"Dynamical theory of the electromagnetic field"*, formally published in Phil. Trans. Roy. Soc. London, Vol. CLV
1866	Bakerian Lecture of the Royal Society: *"On the viscosity or internal friction of air and other gases"*, Phil. Trans. Roy. Soc. London, Vol. CLVI. Includes measurements made in his London attic.

Key dates in the life of Maxwell

1868	*"On a method of making a direct comparison of electrostatic with electromagnetic force; with a note on the electromagnetic theory of light"*, Phil. Trans. Roy. Soc. London, Vol. CLVIII. Includes consequence of definitions of electromagnetic and electrostatic units of electric charge which makes their ratio equal to the speed of light
1868	*"On governors"*, Proc. Roy. Soc. London, Vol. XVI. First mathematical treatment of feedback leading to control theory and cybernetics
1869	Awarded Keith Medal, Royal Society of Edinburgh
1870	*"On reciprocal figures, frames and diagrams of forces"*, Trans. Roy. Soc. Edinburgh, Vol. 26. This follow-up to a paper by G B Airy on elasticity led to award (see above) of RSE Keith Medal
1870	*"On hills and dales"*, Phil. Mag., Vol. 40. An early contribution to the mathematics of topology
1870	Awarded Doctor of Law (LLD), University of Edinburgh
1870	Awarded Hopkins Prize, University of Cambridge
1870	Published his textbook *"Theory of Heat"*
1871	Established and directed Cavendish Laboratory, Cambridge, as First Professor of Experimental Physics
1871	Second lecture on colour at Royal Institution *"On colour vision"*
1873	Publication of his *"Treatise on Electricity and Magnetism"*, Oxford University Press
1874	Elected Foreign Honorary Member, American Academy of Arts and Sciences, Boston
1875	Elected Member of American Philosophical Society of Philadelphia
1875	Elected Corresponding Member, Royal Society of Sciences of Göttingen
1876	Awarded Doctor of Civil Law (DCL), University of Oxford
1876	Elected Honorary Member, New York Academy of Sciences
1877	Published his book *"Matter and Motion"*
1877	Elected Member, Royal Academy of Sciences of Amsterdam
1877	Elected Foreign Corresponding Member, Mathematico-Natural-Science Class of the Imperial Academy of Sciences of Vienna
1878	Delivers Rede Lecture at Cambridge *"The Telephone"*
1878	Volta Medal, Doctor of Sciences honoris causa, University of Pavia
1879	Dies of stomach cancer on 5 November. Buried in the family vault at Parton, Castle Douglas (not far from Glenlair)
2008	Edinburgh statue unveiled.

JAMES CLERK MAXWELL FOUNDATION

This brochure is provided as a reminder of your visit to 14 India Street by the James Clerk Maxwell Foundation **http://www.clerkmaxwellfoundation.org**.

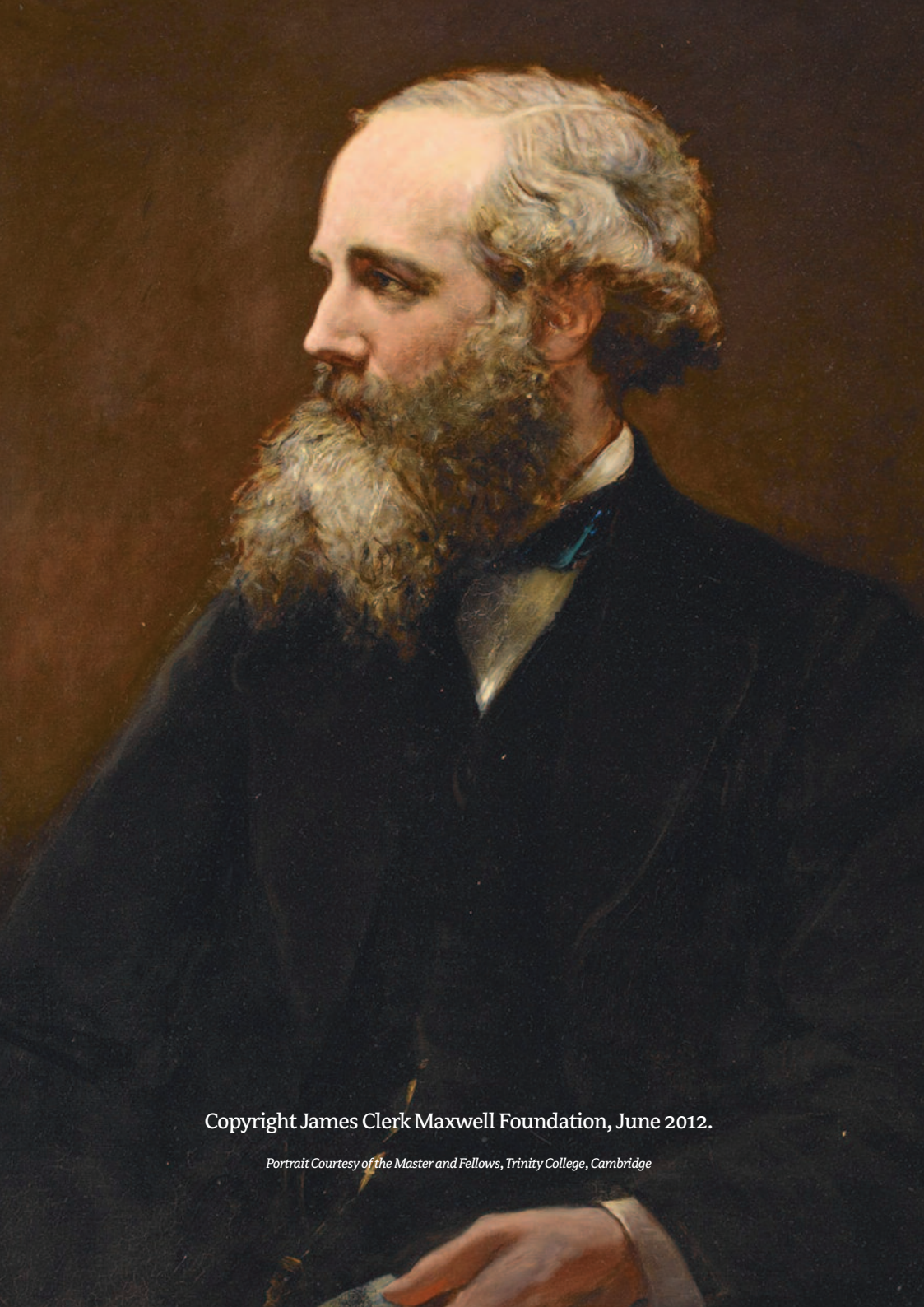
The Foundation was created in 1977 on the initiative and generosity of Sydney Ross, former Professor of Chemistry at Rensselaer Polytechnic Institute, Troy, New York, USA.

The James Clerk Maxwell Foundation's objectives are:

- To display the history of Maxwell's family and his many technical advances, in a simple museum, within his birthplace.
- To provide, in his birthplace, an attractive and stimulating environment for mathematicians, scientists and engineers from all over the world to meet in seminars, symposia, workshops and courses.
- To encourage young students to become mathematicians, scientists and engineers through educational support grants and James Clerk Maxwell Foundation prize awards.
- To increase public awareness of the foundations laid by James Clerk Maxwell for the increasingly pervasive technologies of today, e.g. through meetings, exhibitions, lectures, and cultural events.

Donations will be gratefully received by the Foundation to continue maintaining this house in Maxwell's memory and in supporting our university scholarships, prizes, lectures and other activities which encourage the continuation of Maxwell's legacy.


JAMES



Portrait Courtesy of the Master and Fellows, Trinity College, Cambridge