JAMES CLERK MAXWELL

Obituary by Professor Peter Guthrie Tait ,
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JAMES CLERK MAXWELL, born in 1831, was the only son of John Clerk Maxwell of Middlebie. His grandfather, Captain James Clerk, was a cadet of the old Scottish family of Clerk of Penicuick, being a younger brother of Sir John Clerk of Penicuick. Captain James Clerk had two sons and a daughter—the Right Hon. Sir George Clerk of Penicuick, Bart., the above John Clerk Maxwell, and Isabella, who married James Wedderburn, Solicitor-General of Scotland. Sir George Clerk succeeded to the estate of Penicuick, and the younger brother, John, to the estate of Wether Corsock, part of the estate of Middlebie. This estate had come into the family through the marriage in a former generation of a cousin of the Penicuicks with a Miss Maxwell. Their daughter married Sir George Clerk (grandfather of the present baronet) and was Lady Clerk Maxwell. John Clerk assumed the name of Maxwell on succeeding to the property, which by the entail of Penicuick could not be held by the owner of that estate. John Clerk Maxwell was called to the Scottish bar, but seldom practised, and he was a well-known member of this Society. He lost his wife soon after his marriage, and lived a retired life, devoting himself to the care of his estates and the education of his son.

When I first made Clerk-Maxwell's acquaintance about thirty-five years ago, at the Edinburgh Academy, he was a year before me, being in the fifth class while I was in the fourth.

At school he was at first regarded as shy and rather dull; he made no friendships, and he spent his occasional holidays in reading old ballads, drawing curious diagrams, and making rude mechanical models. His absorption in such pursuits, totally unintelligible to his schoolfellows (who were then quite innocent of mathematics), of course procured him a not very complimentary nickname, which I know is still remembered by many .Fellows of this Society. About the middle of his school career, however, he surprised his companions by suddenly becoming one of the most brilliant among them, gaining high, and sometimes the highest, prizes for Scholarship, Mathematics, and English verse composition. From this time forward I became very intimate with him, and we discussed together, with school-boy enthusiasm, numerous curious problems, among which I remember particularly the various plane sections of a ring or *tore,* and the form of a cylindrical mirror which should show one his own image *unpervcrted.* I still possess some of the MSS. which we exchanged in 1846 and early in 1847. Those by Maxwell are on *"The Conical Pendulum*," *"Descartes' Ovals,*" *"Meloid and Apioid*," and *"Trifocal Curves."* All are drawn up in strict geometrical form and divided into consecutive propositions. The three latter are connected with his first published paper, communicated by Forbes to this Society and printed in our " Proceedings," vol. ii, under the title *"On the Description of Oval Curves, and those having a plurality of foci"* (1846).

At the time when these papers were written he had received no instruction in Mathematics beyond a few books of Euclid, and the merest elements of Algebra.

The winter of 1847 found us together in the classes of Forbes and Kelland, where he highly distinguished himself. With the former he was a particular favourite, being admitted to the free use of the class apparatus for original experiments. He lingered here behind most of his former associates, having spent three years at the University of Edinburgh, working (without any assistance or supervision) with physical and chemical apparatus, and devouring all sorts of scientific works in the library[1]. During this period he wrote two valuable papers, which are published in our " Transactions," on "*The Theory of Rolling Curves*," and "*On the Equilibrium of Elastic Solids*." Thus he brought to Cambridge in the autumn of 1850 a mass of knowledge which was really immense for so young a man, but in a state of disorder appalling to his methodical private tutor. Though that tutor was William Hopkins, the pupil to a great extent took his own way; and it may safely he said that no high wrangler of recent years ever entered the Senate-House more imperfectly trained to produce "paying" work than did Clerk Maxwell. But by sheer strength of intellect, though with the very minimum of knowledge how to use it to advantage under the conditions of the examination, he obtained the

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- [1] From the University Library lists for this period it appears that Maxwell perused at home Fourier's *Theorie de la Chaleur,* Monge's *Geomitrie Descriptive,* Newton's *Optics,* Willis's *Principles of Mechanism,* Cauchy's C*alcul Differential,* Taylor's *Scientific Memoirs,* and many other works of a high order. Unfortunately no record is kept of books consulted in the reading-room.

position of Second Wrangler, and was bracketed equal with the Senior Wrangler in the higher ordeal of the Smith's Prizes. His name appears in the Cambridge " Calendar " as Maxwell of Trinity, but he was originally entered at Peterhouse, and kept his first term there, in that small but most ancient foundation which has of late furnished Scotland with the majority of the Professors of Mathematics and Natural Philosophy in her four universities.

In 1856 he became Professor of Natural Philosophy in Marischal College, Aberdeen; in 1860, Professor of Physics and Astronomy in King's College, London. He was successively Scholar and Fellow of Trinity; and was elected au Honorary Fellow of Trinity when he finally became, in 1871, Professor of Experimental Physics in the University of Cambridge. There can be no doubt that the post to which he was ultimately called was one for which he was in every way pre-eminently qualified; and the Cavendish Laboratory, erected and furnished under his supervision, remains as remarkable a monument to his wide-ranging practical knowledge and theoretical skill as it is to the well-directed munificence of its noble founder.

If the title of mathematician be restricted (as it too commonly is) to those who possess peculiarly ready mastery over symbols, whether they try to understand the significance of each stop or no, Maxwell was not, and certainly never attempted to he, in the foremost rank of mathematicians. He was slow in "writing out," and avoided as far as he could the intricacies of analysis. He preferred always to have before him a geometrical or physical representation of the problem in which he was engaged, and to take all his steps with the aid of this: afterwards, when necessary, translating them into symbols. In the comparative paucity of symbols in many of his great papers, and in the way in which, when wanted, they seem to grow full-blown from pages of ordinary text, his writings resemble much those of Sir William Thomson, which in early life he had with great wisdom chosen as a model.

There can be no doubt that in this habit, of constructing a mental representation of every problem, lay one of the chief secrets of his wonderful success as an investigator. To this were added an extraordinary power of penetration, and an altogether unusual amount of patient determination. The clearness of his mental vision was quite on a par with that of Faraday; and in this (the true) sense of the word he was a mathematician of the highest order.

But the rapidity of his thinking, which he could not control, was such as to destroy, except for the very highest class of students, the value of his lectures. His books and his written addresses (always gone over twice in MS.) are models of clear and precise exposition; but his *extempore* lectures exhibited, in a manner most aggravating to the listener, the extraordinary fertility of his imagination.

During his undergraduateship in Cambridge he developed the germs of his future great work on "*Electricity and Magnetism*" (1873) in the form of a paper *"On Faraday's Lines of Force,"* which was ultimately printed in 1856 in the "Trans. of the Cam. Phil. Soc." He showed me the MS. of the greater part of it in 1853. It is a paper of great interest in itself, but extremely important as indicating the first steps to such a splendid result. His idea of a fluid, incompressible and without mass, but subject to a species of friction in space, was confessedly adopted from the analogy pointed out by Thomson in 1843 between the steady flow of heat and the phenomena of statical electricity.

In recent years he came to the conclusion that all such analogies, depending as they do on Laplace's equation, were best symbolised by he quaternion notation with Hamilton's ∇ operator; and in consequence, in his work on electricity, he gives the expressions for all the more important physical quantities in their quaternion form, though without employing the calculus itself in their establishment. I have discussed in another place *("Nature,"* vol. vii. p. 478) the various important discoveries in this remarkable work, which of itself is sufficient to secure for its author a foremost place among natural philosophers. I may here state that the main object of the work is to do away with " action at a distance," so far at least as electrical and rnagnetic forces are concerned, and to explain these by means of stresses and motions of the medium which is required to account for the phenomena of light. Maxwell has shown that, on this hypothesis, the velocity of light is the ratio of the electro-magnetic and electro-static units. Since this ratio, and the actual velocity of light, can be determined by absolutely independent experiments, the theory can be put at once to an exceedingly severe preliminary test. Neither quantity is yet fairly known within about 2 or 3 per cent., and the most probable values of both certainly agree more closely than do the separate determinations of either. There can now be little doubt that Maxwell's theory of electrical phenomena rests upon foundations as secure as those of the undulatory theory of light. But the life-long work of its creator has left it still in its infancy, and it will probably require for its proper development the services of whole generations of mathematicians.

The next in point of date of Maxwell's greatest works is his "Essay on the Stability of Saturn's Rings," which obtained the Adams' Prize in 1859. In this admirable investigation he shows that it is dynamically impossible that these rings can be solid, and also that. they cannot be continuous liquid masses ; the only other available hypothesis, viz., that they consist of multitudes of discrete parts, each a satellite, must therefore be the correct one.

Another subject which he treated with great success, as well from the experimental as from the theoretical point of view, was the Perception of Colour, the Primary Colour sensations, and the Nature of Colour Blindness. His earliest paper on these subjects bears date 1855, and the seventh has the date 1872. He received the Rumford Medal from the Royal Society in 1860, *"For his Researches on the Composition of Colours, and other optical papers."* Though a triplicity about colour had long been known or suspected, which Young had (most probably correctly) attributed to the existence of three sensations, and Brewster had erroneously[2] supposed to be objective, Maxwell was the first to make colour-sensation the subject of actual measurement. He proved experimentally that any colour C (given in intensity of illumination as well as in character) may be expressed in terms of three arbitrarily chosen standard colours, X, Y, Z, by the formula

$C = aX + bY + cZ.$

Here *a, b,* c are numerical coefficients, which may be positive or negative; the sign = means " matches," + means " superposed," and - directs the term to be taken to the other side of the equation.

The last of his greatest investigations bore on the Kinetic Theory of Gases. Originating with D. Bernoulli, this theory was advanced by the successive labours of Herapath, Joule, and particularly of Clausius, to such an extent as to put its general accuracy beyond a doubt. But by far the greatest developments it has received are due to Maxwell, part of whose mathematical work has recently been still further extended in some directions by Boltzmann. In this field Maxwell appears as an experimenter (on the laws of gaseous friction) as well as a mathematician. His two latest papers deal with this branch of physics; one is an extension and simplification of some of Boltzmann's chief results, the other treats of the kinetic theory as applied to the motion of the radiometer.

He has written an admirable text-book of the *"Theory of Heat*," which has already gone through several editions, and a very excellent elementary treatise on *"Matter and Motion*." (See, again, "*Nature,*" vol. xvi. p. 119.) Even this, like his other and larger works, is full of valuable matter, worthy of the most attentive perusal not of students alone but of the very foremost scientific men.

Of his other scientific work, which extended over the whole range of physics, I may specially mention the following papers :—

On the transformation of surfaces by bending, " Camb. Phil.Trans.," 1854.

The discovery of the production of double refraction in viscous liquids ("Proc. R.S.," 1873), a late consequence of some of the results of his early paper of 1850.

A general theory of optical instruments, " Quart. Journ. ofMath.," 1858.

On reciprocal figures, frames, and diagrams of forces, " Trans.R.S.E.," 1872. For this paper he obtained the Keith Prize.

His share in the construction of the British Association units of electric resistance, and in the admirable reports of the committee. Also his experimental verification of Ohm's law.

For further particulars recourse must be had to the Royal Society's Catalogue of Scientific Papers.

To these may now be added his numerous contributions to the latest edition of the *" Encyclopaedia Britannica* " *Atom*, *Attraction*, *Capillarity*, &c.; and the laborious task of preparing for the press, with copious and very valuable original notes, the *"Electrical Researches of the Hon. Henry Cavendish."* This

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[2] All we can positively say to be erroneous is some of the principal arguments by which Brewster's view was maintained, for the subjective character of the triplicity has not been absolutely *demonstrated.*

work has appeared only within a month or two, and contains many singular and most unexpected revelations as to the early progress of the science of electricity.

The works which we have mentioned would of themselves indicate extraordinary activity on the part of their author, but they form only a fragment of what he has published; and when we add to this the further statement, that Maxwell was always ready to assist those who sought advice or instruction from him, and that he has read over the proof-sheets of many works by his more intimate friends (enriching them by notes, always valuable and often of the quaintest character), we may well wonder how he found time to do so much.

Maxwell's early skill in versification developed itself in later years into real poetic talent. But it always had an object, and often veiled the keenest satire under an air of charming innocence and naive admiration. No living man has shown a greater power of condensing the whole substance of a question into a few clear and compact sentences than Maxwell exhibits in his verses. As an exceedingly good example of his style we may quote the lines written for the portrait of Cayley, now in Trinity College, Cambridge.

O wretched race of men, to space confined !
What honour shall ye pay to him whose mind
To that which lies beyond hath penetrated !
The symbols he hath formed shall sound his praise,
And lead him on through unimagined ways
To conquests new in worlds not yet created.

First, ye determinants in ordered row
And massive column ranged before him go,
To form a phalanx for his safe protection.
Ye powers of the nth roots of - 1,
Around his head in endless cycles run,
As disembodied spirits of direction.

And yon ye undevelopable scroles,
Above the host wave your emblazoned rolls,
Ruled for the record of his bright inventions.
Ye cubic surfaces, by threes and nines,
Draw round his camp your seven-and-twenty lines,
The seal of Solomon in three dimensions.

March on, symbolic host, with step sublime,
Up to the flaming bounds of space and time;
There halt, until, by Dickenson depicted
In two dimensions, we the form may trace
Of him whose mind, too large for vulgar space,
In n dimensions flourished unrestricted."

Other exquisite specimens are given in *"Nature:"* especially good is his "*Lecture to a Lady on Thomson's Reflectiag Galvanometer*." One of the few others which have been printed was secured by John Blackwood for his Magazine, where it appeared under the title *" British Association, 1874*," in November of that year.

It is to be hoped that these scattered gems may be collected and published, for they are of the very highest interest, as the work during leisure hours of one of the most piercing intellects of modern times. Every one of them contains evidence of close and accurate thought, and many are in the happiest form of epigram.

I cannot adequately express in words the extent of the loss which his early death has inflicted not merely on his personal friends, on this Society, on the University of Cambridge, on the whole scientific world, but also, and most especially, on the cause of common sense, of true science, and of religion itself, in these days of much vain-babbling, pseudo-science, and materialism. But men of his stamp never live in vain; and in one sense at least they cannot die. The spirit of Clerk Maxwell still lives with us in his imperishable writings, and will speak to the next generation by the lips of those who have caught inspiration from his teachings and example.

Scotland may well be proud of the galaxy of grand scientific men whom she numbers among her own recently lost ones ; yet even in a company which includes Brewster, Forbes, Graham, Rowan Hamilton, Rankine, and Archibald Smith, she will assign a place in the very front rank to James Clerk Maxwell.