James Clerk Maxwell – Scotland's Greatest Physicist

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It is one of the great anomalies of the celebration of Scottish genius that the achievements of James Clerk Maxwell have figured so marginally in that extraordinary panoply. Among professional scientists he is accorded a status comparable to that of Newton and Einstein. Peter Harman, the editor of Maxwell's Letters and Papers, has written "James Clerk Maxwell's contributions to science … have established his special place (with Isaac Newton and Albert Einstein) in the history of physics."

We need only quote the words of Einstein himself to gauge Maxwell's significance: "We may say that, before Maxwell, Physical Reality, in so far as it was to represent the process of nature, was thought of as consisting in material particles... Since Maxwell's time, Physical Reality has been thought of as represented by continuous fields, governed by partial differential equations, and not capable of any mechanical interpretation. This change in the conception of Reality is the most profound and the most fruitful that physics has experienced since the time of Newton." On the walls of his study, Einstein hung pictures of Maxwell and Faraday.

Einstein's words also spell out one of the difficulties in appreciating Maxwell's genius. While everyone can appreciate Newton's achievements through being taught his laws of motion, for example, force equals mass times acceleration, there is no such simple mechanical picture which can be provided for the fields in physics. And yet, fields are absolutely central to the whole of modern physics. Freeman Dyson has written, "Instead of thinking of mechanical objects as primary and electromagnetic stresses as secondary consequences, you must think of the electromagnetic field as primary and mechanical forces as secondary. The idea that the primary constituents of the universe are fields did not come easily to the physicists of Maxwell's generation. Fields are an abstract concept, far removed from the familiar world of things and forces."

It is significant that the time when Maxwell made his great discoveries coincided with the period when it became essential to express the fundamental laws of physics in mathematical language which was beyond the comprehension of the common reader. While Faraday's understanding the laws of electromagnetism was expressed in terms of images of the behavior of magnetic field lines, the physical content of his discoveries needed the higher mathematics of fields to reveal their deeper content. It is not coincidental that the first chair of theoretical physics in Europe was established for Rudolf Clausius in the 1850s. This epoch can be regarded as the time when the nature of fundamental physics began to diverge from what could be readily comprehended by the interested lay person.

In addition to the problem of articulating exactly what Maxwell's contributions were in everyday terms, Maxwell himself was excessively modest about them. In his presidential address to the British Association for the Advancement of Science in 1870, he reviewed all the other theories but not his own, merely referring to: "Another theory of electromagnetism which I prefer." Again quoting Freeman Dyson, "the moral of this story is that modesty is not always a virtue."

But this is only one part of Maxwell's achievements, which span essentially the whole of physics. His contributions to thermodynamics and the foundations statistical physics were equally profound. His discovery of what we now call the Maxwell distribution of velocities of the particles of a gas was a miracle of economy of expression and has profound implications for all the physical and biological sciences. For example, the very rare events which give rise to biological phenomena and the nuclear reactions which power the Sun are described precisely by the Maxwell distribution. Equally important, the discovery of this distribution had consequences for the fundamentals of thermodynamics and the direction of evolution of natural processes, as embodied in the second law of thermodynamics. Francis Everitt, Maxwell's biographer, rightly remarks that Maxwell's derivation of the Maxwell distribution marked the beginning of a new epoch in physics and is central to everything we do in science nowadays.

Fortunately, the tide is turning. The James Clerk Maxwell Foundation has made enormous efforts to raise an appreciation of Maxwell's genius. The Foundation's Education Centre at 14 India Street in Edinburgh, the house where Maxwell was born, contains a wonderful selection of material on Maxwell, his family and his contributions to science. The Royal Society of Edinburgh is developing plans to honour Maxwell's memory through the commissioning of a statute. There is still a great deal to do. It always saddens me that there is so little mention of Maxwell and his achievements in the great Scottish Museums.

My own view is that it is now quite feasible to use modern methods of presentation to give an appreciation of the profundity of Maxwell's insights. We have developed simulations and presentational methods which illustrate beautifully many of Maxwell's contributions. It is not realistic to expect the lay person to understand the details of the origin of the Maxwell distribution or how the statistical interpretation of the laws of thermodynamics can be related to the law of increase in entropy in natural processes, but it can be now be done by simulations which I presented during the Edinburgh Science Festival.

This year is the 175th Anniversary of Maxwell's birth and there is no better time to begin the process of assimilating his achievements into the consciousness of all Scots and indeed everyone worldwide. By the time of the 200th Anniversary of his birth, let us hope that Maxwell's memory will be as fixed in the Scottish and international imagination as those of Robert Burns, Walter Scott and the myriad of other great Scots.