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Book Review: *The Scientific Letters and Papers of James Clerk Maxwell, Vol. II*

The Scientific Letters and Papers of James Clerk Maxwell, Vol. II, P. M. Harman, ed., Cambridge University Press, Cambridge.

The second volume in this series[1] begins in mid 1862 with Maxwell ensconced in King's College, London, and ends in December 1873 after the formal inauguration of the Cavendish Laboratory, Cambridge, where he spent the rest of his life. During this period statistical physics played a pivotal role in Maxwell's thinking, and there are many items of interest to readers of this journal.

An excellent introduction provides a historical survey of the period covered, and outlines Maxwell's various contributions to the topics in which he maintained an active interest. The relevant letters and papers are identified for each contribution, so that it is easy, for example, to focus attention on those which are concerned with thermodynamics and statistical physics.

The two other contemporary giants responsible for the establishment of statistical physics were Rudolf Clausius, Maxwell's senior, and Ludwig Boltzmann, his junior. The letters provide interesting insight into Maxwell's personal relationship with these professional colleagues. In a historical survey of the kinetic theory of gases Maxwell acknowledges Clausius' seminal innovations "The great development of the theory is due to Clausius." But Clausius' major error was to assume that the velocities of the molecules are equal, and Maxwell corrected this immediately. For some time Clausius remained unconvinced, but Maxwell did not pursue the matter "As he was sure to be converted and I was lazy I said O" Maxwell used Clausius' concepts to initiate a theory of conduction and diffusion, but "Clausius... pointed out *gross* mistakes in M. I have no doubt he has

[1] Vol. I is reviewed in *J. Stat. Phys.* **67**:837–838 (1992).

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some of his own but I have not had the patience to find them out"... "Objections... to the theory of diffusion and conduction were well founded and in his paper on Conduction Clausius greatly advanced the methods of treatment and caused me to go through the subject still in the old style but improved."

Maxwell appreciated Boltzmann's support for his distribution—"The demonstration of the actual law of distribution was given by me in an improved form in my paper on the Dynamical Theory of Gases... and the far more elaborate investigation of Boltzmann has led him to the same result. I am greatly indebted to Boltzmann for the method used in the latter parts of the sketch of the general investigations" But in a letter to P. G. Tait we find the following perceptive observation "By the study of Boltzmann I have become unable to understand him. He could not understand me on account of my shortness and his length was and is an equal stumbling block to me."

An elementary problem to which Maxwell devoted much attention was the thermodynamics and statistical mechanics of an ideal gas in a gravitational field. A modern student would be amazed to find how tortuous was the path to the correct result. In his first attempt at the problem, Maxwell reached a surprising conclusion "Hence the condition of final equilibrium of heat in a gas acted on by gravity is one of mechanical instability so that such a mass of gas left to itself will perpetually be converting part of its heat into visible motion or currents and the energy thus developed will be reconverted into heat by friction." This seemed to conflict with the second law of thermodynamics, and, in a letter to William Thomson, Maxwell states "so there remains as far as I can see a collision between Dynamics and thermodynamics." Fortunately, before he could publish this strange result Maxwell discovered an error, and concluded that the temperature would *increase* with height! This was stated in a paper as submitted to the Royal Society in 1866. But how could one account for the observed *decrease* of temperature with height? "This state would be produced by winds alone, and is no doubt greatly influenced by the effects of radiation. A perfectly calm and sunless atmosphere would be coldest below."

Maxwell then discovered another error, and produced the correct solution, that the temperature is independent of height, which he published as an appendix to his Royal Society paper. It is noteworthy that Thomson who refereed the paper failed to spot the error "What the flaw may be in Maxwell's investigation if any, I have not been able to see."

In 1873 this correct result, which Maxwell had reproduced in 1871 in his *Theory of Heat*, was challenged by Francis Guthrie, Principal of a small college in South Africa. In a letter to *Nature* Guthrie argued, on the basis

of the kinetic theory of gases, that the velocity of molecules in an upper layer must be less than those in a lower layer, and hence that the temperature must decrease with height. Maxwell replied very courteously that Guthrie had not taken account of the change in density with height, which exactly counterbalances the effect he had described. A few months later Guthrie returned to the attack with an alternative more comprehensive analysis; this time Maxwell pointed out that the error lay in assuming that the velocities of all the molecules are equal instead of following the appropriate statistical distribution. Two more letters were exchanged in the following year, and are to be reproduced in Vol. III of the series. Since none of these letters to *Nature* are reproduced in the official edition of Maxwell's scientific papers, it is useful to have them available elsewhere.

Another useful paper not previously published consists of manuscript notes on the history of the kinetic theory of gases. These were prepared in response to a request from Thomson "on dynamical Theory of Gases, Diffusion and all who worked meritoriously on it, whether experimentally or theoretically and *their merits carefully weighed*," which he wished to use for the Presidential Address to the British Association in 1871. Maxwell fulfilled this commission with his usual care and accuracy. Although Thomson used only a fraction of the material which Maxwell had prepared, he did at least refer to "the deeply penetrating genius of Maxwell" which had applied the theory to viscosity and thermal conductivity.

Naturally there are letters which reflect on Maxwell's academic career, and two of them were of particular interest to the present reviewer. In a letter to Thomson dated Oct. 15th 1864 Maxwell gives an early indication of his intention to resign from the Professorship of Natural Philosophy at King's College, London (the actual resignation took place on Feb. 10th 1865). This is powerful additional evidence to scotch the rumour that he was asked to resign by the Governors because he could not keep order at lectures.[2]

The second relates to Maxwell's candidacy in November 1868 (when he had moved back to his home in Scotland) for the Principalship of the United College of St. Andrews. In a letter dated Nov. 3rd Maxwell stated that he had come to a decision not to stand. But letters written a few days later show that he changed his mind, and enjoyed the support of 6 of the 9 professors of the college. His biographer, Lewis Campbell, for his own personal reasons, failed to mention this change of mind. It is good to have the record set straight. Amazingly, but fortunately for Cambridge, Maxwell was not appointed (see footnote 2).

[2] C. Domb, *Notes and Records of the Royal Society* **35**:67–103 (1980).

This book represents a valuable scholarly addition to the literature on Maxwell. It is beautifully produced, and will undoubtedly provide source material for much historical research.

C. Domb
Department of Physics
Bar-Ilan University
Ramat-Gan 52900, Israel