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Book Review: *Statistical Physics and the Atomic Theory of Matter, from Boyle and Newton to Landau and Onsager*

Statistical Physics and the Atomic Theory of Matter, from Boyle and Newton to Landau and Onsager. Stephen G. Brush.

Imagine going back in time and meeting with the great physicists of a previous era. Could you explain to them our view of their outstanding problems and convince them to abandon their theories? Brush, in a masterful account of the history of statistical and atomic physics, shows what difficulties you might encounter. As with Brush's first chapter, let us take the kinetic theory of gases as an example.

Daniel Bernoulli in 1738 and John Herapath in 1820 did produce essentially correct theories, both of which were ignored. Why? First, there were many competing theories, and before the existence of atoms was established the notion of random motions and collisions determining natural phenomena was ridiculed. The first incorrect theory was due to Newton. He showed that a static gas consisting of particles interacting with an inverse distance force law leads to Boyle's law, $PV = \text{const}$. It was widely assumed that Newton proved that a gas consists of interacting static particles, although Newton himself never claimed this. Brush points out the irony of Newton's work delaying progress in the theory of gases by showing (from a Newton manuscript published only in 1965) that Newton essentially calculated a proper kinetic gas pressure in his unusual derivation of centrifugal force. He calculated the force due to impacts (not action at a distance) of a point mass bouncing around in a sphere. Brush states "Newton should have discovered the kinetic theory of gases." Although the book is written at a level which can be understood by undergraduates, it is full of such wonderful tales and insights, many of which are probably unknown even to experts in statistical mechanics.

The kinetic theory ran into further competition when infrared radiation was discovered and it was thought that a wave theory of heat was needed. Of course, today we would say that light is a form of energy which can be converted into heat. More competition came from the caloric

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theory, which treated heat as a substance. This theory was predominent in the early 1800's and gave us much of our terminology such as calories and latent heat.

Finally the work of Clausius, Maxwell, and Boltzman succeeded in demonstrating the validity of the kinetic theory of gases. However, Brush recounts how Maxwell began by attacking this theory. Maxwell's calculations showed that viscosity would be independent of density, which was contrary to published experimental results. Eventually, Maxwell's prediction was borne out by his own more exact experiments.

Brush has admirally succeeded in giving the reader a proper historical perspective of the advancement of science by not only discussing the canonical path to understanding but by also following many of the fascinating dead ends. The interplay between theory and experiment is also stressed and the reader gets a good sense of the confusion in a field before the key experiment is performed or key concept is developed.

Questions of irreversibility arise from the kinetic theory and this is the topic of the second chapter; the well-known story of the development of quantum theory is given in the third chapter. The fourth chapter, in part, tells the fascinating story of how the quantum mechanical calculations of the ionization of an atom and the introduction of quantum statistics led to a revolution in the understanding of stellar atmospheres and stellar evolution. Here Brush misses the opportunity to cite the delightful paper of Dirac in *History of Twentieth Century Physics*, Varenna Summer School (Academic Press, New York, 1977), which gives a personal account of the invention of Fermi–Dirac statistics.

Chapter Four also gives an exceptionally lucid account of theories of Landau, London, Tisza, and Feynmann on superfluidity. Brush writes about helium II that the discovery of its extremely low viscosity was reported in the same issue of *Nature* by Kapitza and by J. F. Allen and A. D. Misener. Kapitza had the dramatic flair to call the phenomenon "superfluidity" and his work is better remembered.

Chapter Five gives a good historical survey of the advances in understanding interatomic forces, and Chapter Six follows the development of the physics of phase transitions. An emphasis is placed on the Ising model which was suggested by Lenz to Ising as a Ph. D. project. Brush could have pointed out the parallel with the Potts model which was suggested by Domb in a similar manner.

Brush's history is anything but dull. His well-researched, accurate account of the development of statistical and atomic physics is peppered with many delightful stories and remarks, e.g., that Newton worried about irreversibility and did not believe in a clockwork universe; Euler (not Newton) introduced $F = ma$; Boyle credits Richard Townley for his law, but he should have also credited Henry Power; Dalton fudged his data on atomic weights to get what he thought were correct results, but were not because he did not understand how atoms could combine to form molecules; Bohr proved van Leeuwen's theorem on zero diamagnetic susceptibility for classical systems in his 1911 Ph. D. thesis, which was only available in Danish until 1972; J. Jones married Kathleen Lennard and then changed his name to Lennard-Jones; Gibbs published in the Connecticut Academy of Sciences but wisely sent reprints to European scientists; the expansion of water upon freezing was suggested as a way to run a machine violating the second law of thermodynamics; etc.

I would recommend this fine book to anyone, from pedestrians to experts, who wish to gain a better understanding of the evolution of scientific thought. Let us hope that a physicist such as Brush will write such a fine history of our era two hundred years hence.

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