PREFACE

David Goodstein.....

'Ludwig Boltzmann, who spent much of his life studying statistical mechanics, died in 1906, by his own hand. Paul Ehrenfest, carrying on the work, died similarly in 1933. Now it is our turn to study statistical mechanics.

Perhaps it will be wise to approach the subject cautiously.'

— in *States of Matter*, 1975, Dover N.Y.

Statistical Mechanics, more than any other branch of Physics, is beset with problems of methodology and presentation. Philosophers have argued over the meaning of probability, particularly when applied to a single "event". Mathematicians have neatly side-stepped the issue by stripping away physical interpretation and treating probability simply as a "measure" accompanied by a set of rules. But disengaging from reality in this way is of scant use to Physics. For Physicists, probability and the statistical method continue to cause their share of anguish. The statistical method was a contributory factor to Boltzmann's suicide and possibly to that of Paul Ehrenfest. Even today the conundrums of Quantum Mechanics have aspects of probability at their heart.

In Statistical Mechanics, the operational approach of the mathematicians is paralleled by the Information Theory approach of E. T. Jaynes. True, this method is championed by some outstanding pedagogues, but I confess to finding it distinctly unappealing. Certainly it might be an expedient way to obtain results, but (to my mind) it obscures *understanding*. And understanding is central to the Physicist's endeavours. By contrast, the ensemble formalism of scholars such as T. L. Hill provides maximum

clarity and physical meaning. Some might find this overly formal; I find it distinctly appealing.

The second structural issue is the relationship between Statistical Mechanics and the older discipline of Thermodynamics. Should these be developed independently or are they better treated in a unified manner? Landau was a strong supporter of the latter view and I have mostly been persuaded by his arguments. At the undergraduate level this philosophy benefited from the magnificent exposition of Reif (also his volume in the Berkley Physics series). It is probable that this had a major impact on the intellectual formation of many of today's professional physicists. It was certainly an ideal preparation for study of the appropriate Landau and Lifshitz volume(s). Nevertheless there is no doubt that classical thermodynamics has its strengths. Most important is the model-independence of its results. Aspects of its abstract formalism may deter some and indeed parts of its deeper logic may be obscure: witness the gradual conversion to the Carathéodory viewpoint by Zemansky through the many editions of his Thermodynamics textbook. These days the logical aspects of Classical Thermodynamics have been elegantly clarified and reformulated by Callen, but this is probably not appropriate at an undergraduate level.

Regardless of the deeper philosophical issues, this second matter has been mostly resolved through necessity. The increasing pressure on the undergraduate curriculum means that in most UK universities there is no longer the space available to present self-contained courses on Classical Thermodynamics and Statistical Mechanics. Indeed this is the case at Royal Holloway University of London. However the introduction of the four-year undergraduate integrated Masters degree, the M.Sci or M.Phys, has helped and allowed the incorporation of some more advanced material into the degree programmes.

Within the University of London, King's, Queen Mary, Royal Holloway, and University Colleges collaborate in the joint teaching of the fourth year of the M.Sci degree, with lectures held in central London. This has allowed a wide range of courses to be provided, many of which are at the cutting edge of the subject. And at the same time this has given the opportunity for a more detailed coverage of some material latterly squeezed out of the traditional three-year B.Sc. degrees.

This book has arisen out of such an intercollegiate course in Statistical Mechanics that I have taught to M.Sci fourth year students over the last ten or so years. Such intercollegiate teaching presents its own challenges. At the completion of their third year, students are required to have reached

a common standard and level for embarking on the intercollegiate fourth year, although presentation and flavour will have been different in each college. This is particularly the case in the area of thermal physics, for the reasons outlined in the first few paragraphs above. And, because of this, the learning material for this course provided to students included some more elementary "foundation" material, albeit presented from a slightly more mature standpoint. Approximately half the material of Chapters One and Two falls into this category.

This was a "paperless" course, whereby students were provided with lecture notes and other learning material on the web. That included the lecture calendar, problem exercises, etc., all of which students could access remotely from their home college or from elsewhere. I was alerted to the wider appeal of the course material when I started to receive requests from students, outside London and around the world, for answers to problem exercises (often with deadlines!) and queries about unclear portions of the notes. This became strikingly poignant on occasions when the college web service was interrupted. Then I would often find frantic email enquiries asking where the material had gone. So when I was approached by Imperial College Press to consider producing a book version of the course, I eventually agreed. This book comprises a re-working of the course material, incorporating changes and suggestions from the various cohorts of students, colleagues and reviewers commissioned by ICP.

Electromagnetic units have traditionally been the cause of many problems to students learning their Physics from a range of sources. It was expected that such difficulties would have been eliminated through the adoption of the SI system. But there has been resistance. Kittel's Solid State Physics book has settled on a compromise whereby many equations are quoted in both their Gaussian and SI forms. I have adopted, almost exclusively, SI units although I am unhappy about aspects of the *B-H* controversy that this can lead to. However readers should note that I use the symbol M to represent total magnetic moment rather than magnetic moment per unit volume. I also confess to the eccentricity of representing the complex dynamical susceptibility as $\chi(\omega) = \chi'(\omega) + i\chi''(\omega)$ rather than the more common complex conjugate form.

I am indebted to many people. Louise, my wife and Abigail, my daughter have become used to an academic husband and father who is so often absent — mentally, if not physically. My teachers Michael Richards and Bill Mullin stimulated what was to become an ongoing obsession with this branch of physics. Their endeavours prepared me for study of

the Landau and Lifshitz volumes; I continue to be thrilled with the incisive clarity and remarkable depth of those books. In my early teaching career I learned much from Roland Dobbs and from Mike Hoare. More recently, Bob Jones has repeatedly demonstrated his encyclopaedic knowledge of statistical mechanics in responding to my obscure questions. His gentle approach has often helped in formulating a student-friendly treatment of a difficult topic. And as ever, John Saunders remains my "critical friend"; he continues to be a constant source of inspiration in so many ways. Above all, I am grateful to the many students whom I have had the privilege of teaching. Their observations, questions, and indeed objections, have helped me to clarify my own views while eliminating sloppy argumentation. Nevertheless, these acknowledgements in no way imply an abrogation of my pedagogical duties. Errors, both of omission and of commission, remain my responsibility alone.

I dedicate this book to the memory of my father, Stanley Cowan, who died in February 1997. He was an engineer of rare ingenuity and a man of exceptional patience. He bore his terminal illness with a serenity that humbled those who knew him. He strongly believed in the power of mathematics in the solution of problems and he imbued me with that belief. He encouraged me to ask questions and although a robust debater, he kept an open mind to the end.

Brian Cowan
December 2004.