Excursions in Thermodynamics and Statistical Mechanics. K. P. N. Murthy, University Press (India) Pvt. Ltd., 3-6-747/1/A Himayatnagar, Hyderabad 500 029. 2009. xix + 132 pp. Price: Rs 175. ISBN 978 81 7371-651-5.

It is always a pleasure to read a book, in which the material has been tested by giving lectures to a number of students at various locations. Then the book bears the imprint of the rich experience of discussions. When the material is presented with interesting anecdotes, copious footnotes, pictures and diagrams, the book will also read well and be attractive. The short monograph under review belongs to this category of easy reading. However, very much like a sugar-coated tablet which masks the bitter taste of the medicine, the monograph also deals with deep scientific issues which have puzzled savants for nearly 200 years and which have vexed philosophers on one hand and physicists and mathematicians on the other. The basic question is why the physical world has irreversibility whereas the underlying basic laws of mechanics etc. are reversible in time. When a glass tumbler falls down and breaks into pieces, why do we not see the broken pieces reassembling to form the tumbler, a question nicely put in the first chapter. There is nothing in the fundamental laws of mechanics to say that the broken pieces cannot reassemble to form the glass tumbler and yet this does not happen.

The author has chosen Ludwig Boltzmann as the central figure in this story, noting that nearly a hundred years ago in 1906 Boltzmann died (actually committed suicide). The roots of the problem started 2000 years ago when the Greek scholars began to grapple with the ideas of atoms as the smallest constituents of matter. The progress made in describing the behaviour of bulk gases in the 15th and 16th century as well as the dramatic development of the laws of mechanics by Newton set the stage for refining the questions (chapter 2). The studies of the thermal behaviour of materials led to the beginnings of the laws of thermodynamics in the 19th century though the studies were initially driven by the so-called caloric theory of heat, which had to be abandoned later (chapter 3). The stage was set for the introduction of the concept of entropy by Clausius in 1865 (chapter 4) showing that entropy increases in any thermodynamic process. Thus thermodynamics of bulk systems has an intrinsic irreversibility in time whereas the laws of mechanics of the constituent elementary particles are reversible in time.

The issue became more complex when in 1872 Boltzmann succeeded in reformulating the description of the collisions among the particles of the gas to develop the equation for the evolution of the molecular distribution function, now commonly called Boltzmann transport equation (chapter 5). The procedure gave a systematic way of developing the kinetic theory of gases, which had been studied on the basis of elastic collisions among the gas molecules by Maxwell who had obtained the distribution of molecular velocities on the basis of purely statistical arguments. Earlier Bernoulli, Herpath and Waterston, the latter two virtually unknown since their papers were rejected for publication, had used the simple arguments of all molecules travelling with the same velocity. While the success with the kinetic theory of gases was clear, the H-function associated with the Boltzmann transport equation never increases with time and thus gives a time asymmetry though the laws describing the collisions among the gases etc. are all symmetric in time. Other paradoxes of the theory were pointed out by Loschmidt and by Zermelo, but the central problem remained. In 1877 Boltzmann went further ahead and gave a purely probability argument connecting H to the probability of finding that state among all the possible states of the system (chapter 6) and defining the entropy in terms of the randomness. As an aside the author points out that the simple equation $S = k\log W$, implied in Boltzmann's work, was first explicitly written down by Max Planck. (Actually it was also Planck who called k as the Boltzmann's constant, related to the Gas constant and the Avogadro number.) This new procedure gave the absolute value of entropy of the ideal gas, as was checked with the experimental observations later by Sackur and by Tetrode. Thus the thermodynamic procedures, the probabilistic arguments or the kinetic theory arguments all reinforced the central problem of the irreversibility of macro phenomena, in spite of the mechanics of the micro world being reversible in time.

An alternate method of calculating the thermodynamic properties by averaging over the different states with different probabilities was developed by Gibbs. The averaging over the ensembles at a given time (chapter 7) turned out to be the same as the averaging of a kinetic trajectory over its time evolution, now called as the ergodic principle. The statistical thermodynamics using the ensemble method became hugely successful in numerous situations and became a standard procedure in theoretical studies. Yet, the reversibility versus irreversibility dilemma continued.

The author then moves to the modern phase of attempting to answer the dilemma on the basis of the chaos theory. In the 1960s, while studying the nonlinear coupled equations for atmospheric behaviour, Lorenz discovered that phase trajectories starting from close phase space points diverge exponentially and become completely unrelated (chapter 8). This chaotic behaviour of nonlinear dynamical systems had been known since the time of Poincaré (1890s) and methods of characterizing such chaos had been developed by Lyapunov, but these were thought to be mathematical curiosities. The fact, that *determinism does not guarantee predictability when nonlinearities exist in the system*, was recognized as a key to understand the above-mentioned dilemma. Chaos and nonlinear dynamics provide the link between deterministic macro level equations and the stochastic macro behaviour, the paradox which was worrying Boltzmann and many others. Even if the collisions between gas molecules follow well defined equations which are reversible in time, the time evolution of the system can take numerous different paths and hence can be handled only by statistical averaging. The new procedures have enabled the concepts of entropy etc. to be extended to non-equilibrium steady state systems also. For example, one can study the entropy fluctuations (chapter 9), work fluctuations (chapter 10) and heat fluctuations (chapter 11) in steady state non-equilibrium systems. These are among the items of contemporary research in statistical mechanics.

The epilogue (chapter 12) nostalgically surveys the journey and this is followed by the references cited in the text as well as a list of supplementary reading. There is a short index at the end. The book is thus a simple guide to some of the recent developments in thermodynamics and statistical physics, extending the understanding of equilibrium systems to non-equilibrium systems in a steady driven state. It is not a textbook nor will a new entrant be able to appreciate the finer aspects of the exposition.

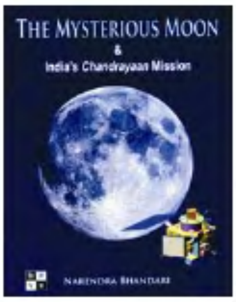
What more should one say, in addition to recommending it for reading as a supplementary material? Slips in editorial work are very few, like top/bottom instead of left/right on page 15. Should anything be added in say the next re-printing? Although the fluctuation of energy in a canonical ensemble is discussed in section 7.2.1, a simple extension that, for a gas of N particles, the mean square fluctuation goes as $1/N$ and is hence too small to be observed for almost all cases, would have been a useful example of the stability of the thermodynamic averages. In chaos theory the concept of 'attractors' has a special meaning and yet the word is quietly slipped in chapter 8 without any explanation.

Among the titbits about curious historical events, one may add the famous advice of Lord Rayleigh to ambitious young scholars, which is valid even today. Rayleigh as the Secretary of the Royal Society, London, got the paper of J. J. Waterston of Bombay published in 1893, though it was submitted in 1845 and rejected by the referees. Rayleigh wrote a 5-page introduction to the 75-page paper (*Philos. Trans. R. Soc. London*, 1893, 183A, 1–79), starting by how his attention was drawn to this paper buried in the archives of the Society and then going on to say 'The history of this paper suggests that highly speculative investigations, especially by an unknown author, are best brought before the world through some other channel than a scientific society, which naturally hesitates to admit into its printed records matters of uncertain value. Perhaps one may go further and say that a young author who believes himself capable of great things would usually do well to secure the favourable recognition of the scientific world by work whose scope is limited and whose value is easily judged, before embarking upon higher flights'.

On the scientific front, one can be easily carried away by the rich patterns in chaos theory, accessible to anyone with a computing system. Clearly determinism does not necessarily imply predictability in nonlinear systems and the author likes us to believe that this has solved the dilemma of irreversibility in the micro-world derived from the reversible laws of the micro-world. However the question can be asked, whether nonlinearity is absolutely necessary? Will a purely linear system of a large number of particles show statistical/thermodynamic averaging, even though chaos will not occur in a purely linear system? One may conjecture that the answer is yes. Ergodic theories in the hands of Caratheodory, Birkhoff and others appeared to show some path with the metric transitivity of the phase space. Yet, the answer is not proved to everyone's satisfaction. As the South Indian proverb says, 'We must leave something for tomorrow'.

E. S. RAJA GOPAL

Department of Physics,
Indian Institute of Science,
Bangalore 560 012, India
e-mail: gopal@physics.iisc.ernet.in



The Mysterious Moon & India's Chandrayaan Mission. Narendra Bhandari. Vigyan Prasar, Dept of Science and Technology, A-50, Institutional Area, Sector-62, Noida 201 307. 2008. xix + 88 pp. Price: Rs 195. ISBN: 978-81-7480-177-7.

Yes, India has finally reached out to Moon. The success of *Chandrayaan-1* mission is a monumental achievement by Indian Space Research Organization (ISRO). This mission has triggered the imagination of young India as never before. In the backdrop of the successful launch of *Chandrayaan-1*, it is timely that Vigyan Prasar has brought out a very interesting book on the moon, with the fond hope of rekindling and sustaining the intellectual curiosity of general public on unknown scientific facts about moon.

The moon is probably one of the celestial mysteries that most of us have grown with. The spectacle of a bright moon in the sky on a full moon day is a visual delight and this sight has fascinated mankind since antiquity. When the Americans first landed on moon in the year 1969 it virtually kick started the American space odyssey and in some sense heralded the technological advancement in the American society. Maybe the euphoria generated by *Chandrayaan-1* will also usher something on similar lines in India. With no pretensions, Narendra Bhandari has come out with a rather informative compilation on both the moon and *Chandrayaan-1*. The language in the book is that of a simple popular science article that can be easily understood by non-specialists. I personally believe that this book should find a place in most of the high schools and colleges so that most students will have an opportunity to satisfy their intellectual curiosity about the moon. This certainly does not imply that the book may not be interesting to practising scientists and engineers. Maybe the research community may find the information in the book rather brief giving the reader a feeling of watching the trailer of a very absorbing thriller movie. But the book does succeed in holding your attention till the end and does encourage you to read further about the subject.

The major part of the book is dedicated to explaining the various facets of the moon and the last few chapters of the book describes the *Chandrayaan-1* mission. The book is full of interesting colourful illustrations and photographs. The pictorial depiction of earth and the internal structure of the moon, different chemical and mineral compositions in it are very informative with clear and lucid descriptions. I am not sure if many of us knew that there are craters on the moon that have been named after Vikram Sarabhai, a renowned space scientist and well-known astrophysicist Meghnad Saha. Chapter 3 comprises interesting