J. Plasma Physics (2009), *vol.* 75, *part* 5, *pp.* 709–711.
Printed in the United Kingdom

BOOK REVIEW

Elementary Physics of Complex Plasmas, Lecture Notes on Physics, vol. 731, by V. N. Tsytovich, G. E. Morfill, S. V. Vladimirov and H. M. Thomas, Springer, Berlin Heidelberg, 2008, DOI 10.1007/978-3-540-29003-2, ISBN 0075-8450, 370 pages including index.

doi:10.1017/S0022377809990225

The treatise *Elementary Physics of Complex Plasmas* was written primarily for researchers in the field of complex (dusty) plasmas, but it contains enough introductory material to be suitable as a textbook for a topical course on the physics of complex plasmas. It could also be used as a reference text along with any of the other books on dusty plasma physics such as the text of Shukla and Mamun, Verheest's book on waves in dusty plasmas or the book edited by Bouchoule dealing with the technological applications of dusty plasmas. The work by Tsytovich, Morfill, Vladimirov and Thomas places a larger emphasis on plasma crystals; two of the eight chapters are devoted entirely to this topic.

The dominant theme emphasized throughout the book is that complex plasmas are a new branch of physics that is of general interest. Thus the book is targeted at not only dusty plasma researchers but also physicists in the field of soft condensed matter or scientists interested in interdisciplinary problems of self-organization. Indeed, the first chapter of the book argues the case that the complex plasma state is an unusual state of matter that is qualitatively different from the 'ordinary' states of matter. In addition to providing a comprehensive general introduction to the fundamental issues in complex plasmas, Chapter 1 also contains a summary of the historical development of the field. Two additional points made by the authors is that the field of complex plasmas is still relatively young and that many new discoveries can be expected. These points then are taken up in Chapter 2 which discusses future technologies that may arise from the scientific discoveries in complex plasmas. These applications include new materials fabricated in complex plasmas and various environmental issues in which dust or aerosol play a role. Technological problems arising from the presence of dust in fusion plasmas are also considered.

Chapter 3 provides a thorough treatment of the fundamental processes in complex plasmas – screening of dust grains in a plasma, charging theories and forces. The discussion of screening begins by pointing out that the usual derivation of the Debye screening length based on the linear expansion of the Boltzmann distribution for the electrons and ions is usually not valid in present complex plasma experiments. Screening in complex plasmas is inherently nonlinear. An extensive account of dust-charging theories is given in which the usual orbital-motion-limited (OML) theory is presented as well as extensions to the OML approach that are necessary to take into account the close-packing effect, the role of ion drift and strong magnetic fields. Two alternate charging theories are also discussed: the radial drift limited model and the diffusion-limited model that attempts to take into account ion-neutral collisions. The last part of Chapter 3 analyses the forces on the ions and electrons due to the dust and the forces on the dust grains. The electric field force,

gravity, the ion drag force, thermophoretic force and neutral drag force are among the forces considered.

Chapter 4 considers collective effects in complex plasmas with an emphasis on the novel properties which distinguish it from multi-component plasmas. The authors point out that this new state of matter is an open system in which the dissipation of plasma on the dust grains requires the presence of external sources to maintain the equilibrium state. Another effect which is novel to the complex plasma state is the fact that the charge on a grain is not a fixed quantity. These new effects must be taken into account in the derivation of dispersion relations for low-frequency modes, such as the dust ion sound wave and the dust acoustic wave. Much attention is paid to the proper analysis of the zero-order state (ground state) around which the linearization is performed. The 'universal' nature of the instabilities that result from the new dissipation mechanism is extensively discussed. The chapter includes a detailed review of experimental work on waves in dusty plasmas.

The subject of Chapter 5 is collective and non-collective grain pair interactions. The discussion proceeds from a model of 'test' grains in a 'sea' of all other grains. The fact that the complex plasma is an open system provides a new mechanism through which the pair grain interaction depends on the particle density. Although the particle charges are all of the same sign, the absorption of the plasma flux can lead to an attractive pair interaction when the particles are at sufficiently large distances. The shadow non-collective attraction forces due to the ion and neutral fluxes are discussed. The collective interaction is considered for the cases of both linear and nonlinear screening. Measurements of the screened potentials obtained from detailed experimental observations of grain–grain interactions are presented and compared with the theoretical predictions.

Experiments on plasma crystals and long-range correlations are the subject of Chapter 6. A general discussion of the present level of understanding of the formation of plasma crystals from the point of view of the complex plasma phase transition is given. The experimental techniques used to produce and diagnose plasma crystals are described here as well as observations of the structure of dust crystals, dislocations and defects and the melting and phase transitions. In their concluding remarks to this chapter, the authors point out that the study of plasma crystals has been driven largely by the discoveries in the lab; in this case a complete theoretical description is lagging. It is anticipated that potential industrial applications of plasma crystals will also be driven by the experiments, and this will likely occur before a detailed theoretical foundation is formulated. Chapter 7 continues on the topic of plasma crystals, specifically with monolayer plasma crystals and two-dimensional plasma clusters composed of small numbers of grains. The theory of two-dimensional clusters is presented here. Together, Chapters 6 and 7 provide a comprehensive summary of the present state of understanding of the plasma crystal state.

The concluding chapter of the book, Chapter 8 ('Comments on other dust structures: Concluding remarks') contains some material of a more speculative nature than that found in the previous chapters. The overarching theme here is that the complex plasma, being a very dissipative system, is highly susceptible to structure formation and self-organization processes. For example, in the presence of a cylindrical confining potential, the possibility of forming dust helical structures is discussed. Various other structures are considered such as structures in disordered states, dust voids, dust wall sheaths, dust structures between walls and dust

convection in structures. The chapter concludes with an outlook to future work on complex plasmas.

I would expect that all researchers in the field of complex (dusty) plasmas will want to have a copy of this book, particularly those working on dust crystals. The authors have provided a comprehensive assessment of the field and point out where further work, both experimental and theoretical, needs to be done. This forward-looking approach makes this book extremely useful, not only for present workers in this field but also for researchers who might be contemplating entering this field. The book contains an extensive list of references (just under 500) which will make it very helpful to anyone preparing a manuscript for publication or a research proposal. There were just a few 'annoyances' that I found with the presentation, such as errors in a few references. Also, since most of the theoretical results are presented in non-dimensional form, one often has to search back through earlier chapters for the definitions of various quantities. A list of the definitions of the symbols used throughout the book would have been a welcome addition.

In conclusion, the book by Tsytovich, Morfill, Vladimirov and Thomas is an excellent addition to the present collection of books on complex (dusty) plasmas. This book is recommended to anyone wishing to acquire a firm understanding and appreciation for the unique properties of the complex plasma state.

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