The Physics of Non-Ideal Plasma

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The Physics of Non-Ideal Plasma

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Preface

This book is devoted to the physical properties of dense plasma compressed so strongly that the effects of interparticle interaction are substantial, that is, non-ideal. These non-traditional plasma studies have increased in scale over the last 10–15 years, owing to the development of modern technical projects and facilities whose operation is based on a high local concentration of energy in dense media.

Non-ideal plasma is essential from the standpoint of operation of pulsed thermonuclear reactors with inertial confinement of hot plasma, powerful magnetic-flux and magnetohydrodynamic generators, power-generating plants and rocket engines with gas-phase nuclear reactors, plasmachemical and microwave reactors, plasma generators, and powerful sources of optical and X-ray radiation. Non-ideal plasma occurs as a result of stimulation of matter by strong shock, detonation and electric-explosion waves, concentrated laser radiation, and electron and ion fluxes, under conditions of powerful chemical and nuclear explosions upon pulsed evaporation of the liners of pinches and magnetocumulative generators. Non-ideal plasma occurs during hypersonic motion of bodies in dense planetary atmospheres, as a result of high-velocity impact, and in numerous situations characterized by extreme pressures and temperatures. The physics of electrode, contact and electric-explosion processes, under conditions of vacuum breakdown, are closely related to non-ideal plasma, which is essential to the operation of powerful plasma accelerators, microwave generators and plasma switches. Modern progress in understanding the structure and evolution of the giant planets in the solar system, as well as astrophysical objects, is largely based on the ideas and results of the physics of highly compressed plasma.

Along with the pragmatic interest in high pressure plasma, purely scientific interest is gaining momentum, because it is in this exotic state that the major part of matter in the universe finds itself. Besides, the non-ideality of plasma defines the behavior of matter in a wide range of the phase diagram, from solid and liquid to neutral gas, the phase boundaries of melting and boiling, and the metal-dielectric transition region.

These facts provide a permanent and stable stimulus to intense theoretical and experimental studies, which have recently produced a host of interesting and, what is most important, reliable data on the thermodynamic, optical, electrophysical and transport properties of dense plasma. This concrete information is contained in a wide flow of original publications. This takes place against the background of an increasing number of specialists, both researchers and engineers, who make use of non-ideal plasma to solve most diverse scientific and applied problems.

The present authors have attempted to systematize, generalize, and present, from a single viewpoint, the theoretical and experimental material relating to this new field of science. The contents give a good idea of the scope of the book. They have tried to expand the discussion as much as possible to include cases when non-ideality shows most clearly in the plasma state of matter. Therefore, the interesting problems pertaining to the dense plasma of metals and semiconductors, electrolyte plasma, "cryogenic" highly non-equilibrium plasma, and a detailed discussion of plasma applications have been omitted.

The physics of non-ideal plasma appears to present a very inconvenient subject for pure theory. This is because the strong interparticle interaction impedes the use of the conventional methods of theoretical physics. Therefore, the recent progress in understanding the properties of compressed plasma was only made possible by the emergence of experimental data obtained through non-conventional generation and diagnostic techniques. In this case, the experimental results provide a basis for model theories, as well as for defining the range of applicability of asymptotic approximations. Therefore, the authors tried to maintain the natural proportions between theory and experiment while giving primary consideration to physical results. In their opinion, this is what distinguishes this work from the available (and rather few) review publications in the field.

The authors hope that this book will prove useful to broad sections of specialists by giving them access to original studies and to help them get their bearings amid the present-day problems of dense plasma. The book is written such that the knowledge of standard university courses is sufficient for productive reading.

The physics of non-ideal plasma is developing very rapidly with more and more applications coming to light. Naturally, the material contained in this book will likewise be expanded and complemented. The authors would like to thank the readers in advance for their critical comments and suggestions.

The authors are deeply grateful to L. M. Biberman, E. P. Velikhov, A. M. Prokhorov and A. E. Scheindlin for encouragement and fruitful discussions. Of great value were stimulating discussions and creative contacts with the late Ya. B. Zel'dovich and V. M. Ievlev. The authors are also grateful to all their colleagues who helped to perform the numerous experiments and calculations which form the basis of this book. They are grateful to Henry Bronshtein who made the English translation.

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