Preface

Plasma physics is a discipline that has evolved in an almost explosive way in the past 80 years. Born as a rather marginal subject, the study of the physics of ionized gases, it had a first important application to the theory of the propagation of electromagnetic waves in the Earth's ionosphere. Its importance for astrophysics had an early recognition thanks to the pioneering work of Hannes Alfvén, that prepared the ground for many of the successive developments. A second fundamental field of application of plasma physics opened up when the controlled thermonuclear fusion became one of the leading project in "big science." The interactions between the scientific communities engaged in the main two fields of application, laboratory plasma physics and plasma astrophysics, very limited at beginning, have constantly increased in time with a reciprocal benefit.

Plasmas are the main constituents of the Universe. Therefore, the interpretation of the large amount of information provided by modern observations, both from the ground and from space, requires a working knowledge of plasma physics. The acquisition of such a working knowledge, however, is a slow process since the subject is far from our everyday experience and has the disturbing tendency of becoming complex, even in apparently simple situations. We are convinced that the study of plasma physics must be started relatively early in the university career, as soon as the student has mastered the basic concepts of fluid dynamics and electromagnetic theory.

This book is an outgrowth of the lecture notes of the course taught by the authors for a number of years at the University of Florence and an expanded version of a book previously published in Italian. Given the large number of excellent textbook in plasma physics already available, the obvious question is: why another one? Our purpose in writing this book has been to address a particular audience, namely students with a reasonable good background in mathematics and physics at the undergraduate level who intend to orient their future activity in astrophysics. Our ambition has been to bring the student from the very basic concepts of plasma physics up to some of the more active research fields. We have attempted to maintain a certain balance between mathematical rigor and physical intuition. The possibility of following explicitly the technical details of calculations allows the

student to appreciate the power of mathematics and to acquire the tools necessary to attack new problems on his own. Mathematics can be boring, but is reassuring. We have also tried, whenever possible, to provide physical explanations of the phenomena under discussion, in order to develop the physical insight that allows to understand in a deep and intuitive way the inner workings of nature.

The book is divided in two unequal parts. The first seven chapters cover the fundamental aspects of plasma physics, presented in a traditional way. Although the main emphasis of the book is on fluid models and, in particular, on magnetohydrodynamics, we have attempted to show the logical path that brings us to those models. Therefore, we have included a short outline of kinetic theory, also to prepare the ground for more advanced topics such as the Landau damping and the collisionless shocks. The advantages and the limits of each model are clearly spelled out. The long chapter on instabilities contains, apart from a discussion of the more common cases, such as the Rayleigh–Taylor, Kruskal–Shafranov, and Kelvin–Helmholtz instabilities, the discussion of certain types of instabilities not normally present in introductory textbooks.

The last four chapters are more demanding for the reader as they cover the most advanced material: the properties of collisional and collisionless shocks, magnetic reconnection, the main features of turbulence and the build-up and maintenance of cosmical magnetic fields. All these areas are the subject of an intense research effort worldwide and the students have some trouble finding appropriate description of these subjects at an introductory level. We have tried to provide such an introduction, hoping to bring the reader to the point where he/she will be able to approach and understand the more specialized literature. A Section on Problems and Questions is placed at the end of each Chapter. It contains a small number of problems that should help the student to verify the degree of understanding acquired. Solutions are given for all problems.

When writing this book, we have greatly benefited from numerous discussions and suggestions from our friends and colleagues. We wish to thank them collectively here.

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