The ionized material that constitutes plasma permeates almost all of the universe. This book describes the linear theory of many different waves and instabilities that may propagate in collisionless space plasmas. Electrostatic and electromagnetic fluctuations, and a variety of instablility sources, are considered.

Applications of the theory are discussed with respect to spacecraft observations in the solar wind, terrestrial magnetosheath, magnetosphere and magnetotail and at the bow shock and magnetopause.

Tables at the ends of most chapters summarize wave and instability nomenclature and properties, and problems for the reader to solve are interspersed throughout the text. Together these make this book of great value to both the student and the research worker in space physics.

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Theory of space plasma microinstabilities

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Theory of space plasma microinstabilities

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Preface

If a charged particle species of a collisionless plasma possesses a non-Maxwellian velocity distribution function, a short wavelength normal mode of the system may grow in amplitude. This is a microinstability; its theory is well described by the Vlasov equation. The purpose of this monograph is to describe in an accurate way the theory of damped normal modes and a limited number of microinstabilities that may arise in various space plasma environments.

The two words that best characterize the work described in this book are "limited" and "accurate." In order to keep the discussion limited, I have chosen idealized, not observed, distribution functions. Many spacecraft have provided excellent observations of electron and ion distributions in the Earth's magnetosphere and nearby solar wind. The tremendous variety of these distributions makes it difficult to select a few for special representation. My choice here has been to use Maxwellian or bi-Maxwellian distributions with field-aligned drifts to represent some of the more important general free energy sources. Although the resulting instabilities may not correspond to any particular data set, I hope that each one represents the general properties of a very broad class of data.

To provide accuracy, I have followed the same procedure for each distribution function and plasma model. After assuming a zeroth-order distribution, I derive (or at least explicitly state) the associated dispersion equation without approximation. Because I deal with linear theory throughout this book, it is always straightforward to do this, although the algebra gets tiresome at times. A complete Vlasov dispersion equation involves the sums (and often products) of transcendental functions of a complex variable. Such an equation can be a rich source of physics, but there are often subtleties and surprises along the path to its solution. To make sure that the proper physics is attained throughout this book I numerically solve the complete linear dispersion equation for the waves and instabilities of that dispersion equation and then, when appropriate, use the exact results to justify reductions to analytic forms that simplify the physical interpretation.

This procedure stands in contrast to some of the literature in this field that invokes analytic approximations before computers are brought to bear on the problem. The danger in this procedure is that, because one is dealing with a transcendental equation, inappropriate approximations can change its character, introducing spurious roots or changing the character of true solutions. Because my preference is not to make use of references that may be subject to such errors, you may find some of your favorite citations missing from my list of references. Although I do cite references concerning computer simulations and spacecraft observations, the primary emphasis throughout this book is on linear theory.

This book began as a series of lecture notes that I used to supplement textbook material for an advanced plasma physics course I taught at the University of New Mexico, Los Alamos, in 1981. I gradually added material over the years until 1987, when I became Leader of the Space Plasma Physics Group at the Laboratory. The press of administrative responsibilities then caused the manuscript to be neglected for several years. But the recent departure of my younger child to college has opened up more evening and weekend time for me to work on the book once again; a slight nudge from the good folks at Cambridge University Press and the realization that I had better get the job done before I lost what few plasma insights remained have spurred me to complete this work.

I thank all my colleagues in plasma theory and experiment who, through their unselfish scientific collaborations with me, have substantially contributed to the insights and interpretations found in this book. Among these many individuals I would like to single out Dan Winske, who has been particularly generous, cooperative, and persistent in supporting my efforts to understand the theory of space plasma microinstabilities. And I especially thank my wife, Pat, for her patience and understanding in allowing me to put in the time after hours that has enabled me to, finally, finish this manuscript.

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