Preface

The discovery of chaotic behavior in nonlinear dynamical systems is the third great revolution in physics in the twentieth century – after the theory of relativity and quantum mechanics. Even though, as early as the turn of the 20th century, H. Poincaré had written papers on the predictability of natural phenomena – and even of the universe at large – it wasn't until the 1960s, with the onset of easily available computing resources, that clear evidence of nonpredictability appeared. After that, the theory of chaotic behavior leaped forward, became a part of every branch of science where dynamical systems are studied mathematically. The evidence of nonpredictability also stimulated a great change in the field of classical mechanics itself.

This recent history was foremost in my mind when, several years ago, I was charged with the task of teaching theoretical mechanics to students for the first time. Upon reading through textbooks available at the time, I discovered that few even referred to these new developments in nonlinear dynamical systems. Most textbooks only deal with 'nicely' behaved systems; but since chaotic behavior can appear in practically every nontrivial mechanical system, I felt it essential to include chaotic systems in the presentation of mechanics.

Chaotic motion should not be banished as a mere curiosity to some small part of the book. The reader or student ought to be acquainted with chaotic behavior at an early stage of their study of classical mechanics. She or he should be able to understand when and why a physical system may behave chaotically. I hope that this attitude towards teaching the subject will greatly diminish the necessity to repeat Sir J. Lighthill's apology[†] "on behalf of the broad global fraternity of practitioners of mechanics ... for having misled the general educated public by spreading ideas about the determinism of systems satisfying Newton's laws of motion". I gave the course, and the course gave rise to a book.

Of course, the ideas and methods of classical mechanics are developed in this book also largely within conventional, integrable systems; but the concepts of phase space, first integral and conserved quantity are stressed

[†]Proc.R.Soc.Lond. A**407**,35(1986); I thank a referee for bringing this statement by Lighthill – which encapsulates my view of the situation exactly – to my attention.

right from the beginning. Linear stability analysis is introduced as a first tool to investigate the stability of orbits. With these concepts at hand, chaotic behavior in nonlinear systems is discussed early on in the treatment. Moreover, topics that are relatively uncommon in presentations of classical dynamical systems – such as a particle in a homogeneous magnetic field; various cases of the spinning top; the problem of two centers of force; and the restricted three body problem – are considered. The general conditions for integrability of a dynamical system are presented in the framework of Hamilton-Jacobi theory, and we touch on the stability of planetary motion. Canonical perturbation theory leads finally to the KAM theorem on motion in a system that is nearly integrable.

Problems and examples are included at the end of each chapter; in the text, the symbol (E) denotes that a related exercise appears at the end of the chapter. References to books listed in the Bibliography are denoted [author/s]. These books are a personal selection, and in most cases they have been helpful in the preparation of this book. When proper names of people appear in the index, the page number given refers to the biographical data. The mathematical appendices are not intended to give an introduction to the respective topics, but serve merely as compilations and references.

The first German edition of this book appeared 1993, published by the Universitätsverlag R. Trauner, Linz, Austria; then in 1999, after two more revised German editions, a Ukrainian edition was published by the National Ivan Franko University in Lviv, Ukraine. In the meantime, it seems that the situation concerning the lack of a modern presentation of classical mechanics has not really changed. I hope this book contributes to the vital resurgence of the "old lady" classical mechanics.

I owe many thanks to Prof. B. Schnizer (University of Graz, Austria) for his comments already at an early stage in the book's life, as well as for providing me with important figures; to Dr. Yurij Holovatch (Institute of Condensed Matter Physics of the Ukrainian Academy of Sciences in Lviv, Ukraine) for contributions, correcting errors and many useful comments; John Wojdylo (University of Western Australia), who not only painstakingly transformed my translation into a polished English, but also, on many occasions, provoked clarifications of the physical argument – but he is definitely is not responsible for any remaining vague points in this treatise. Ian Seldrup (World Scientific Publishing, Singapore) patiently and competently conducted the final stages of this book. I also gratefully acknowledge the financial support of the Linzer Hochschulfonds and the City of Linz for the translation.

Linz, June 2002 Harald IRO