

## PREFACE

This book originated from lectures which I gave repeatedly at the University of Frankfurt am Main. The lively interest of the students testified for the need of such a text. Because of the multitude of topics which make up the curriculum, special relativity gets short shrift. On the other hand, monographs in this area are very voluminous and serve better as reference works. In contrast, it should be possible to read through this book on hand in a relatively short time. It contains the material which was treated in a semester of a two-hour-per-week course. However, the presentation is more detailed than it would be in a set of lecture course notes, so that it may serve for private study too.

Since the German version of the book had a very positive reception, it soon became necessary to prepare a new and enlarged edition. The present English text is based on the second German edition, which was published in 1987.

The book provides a short course in special relativity, intended mainly for senior undergraduates or beginning graduate students in physics, mathematics, or related subjects such as astrophysics. It is assumed that the reader already has some basic familiarity with standard course materials. Thus, for example, the famous Michelson-Morley experiment is not once again described in detail.

The advanced reader will soon notice that the emphasis in this work is different from that of most presentations, especially from the so well established older texts. Via the path I follow, one arrives at the essential statements of the theory by a more direct approach. Thus, access to the special theory of relativity is rendered exactly in the spirit of A. Einstein's comment, given on page ten.

After some introductory remarks on the essence of relativity theory the book begins in Chapter 1 with a brief historical outline of the main contributions to its development by H.A.Lorentz, H.Poincaré, A. Einstein, and H. Minkowski. Also the reception of Einstein's crucial

work of 1905 is commented on, as well as the role of the Michelson-Morley experiment in Einstein's reasoning. The Galilean relativity principle and its limits are discussed in Chapter 2. For the establishing of the Lorentz transformation the principle of relativity and the homogeneity and isotropy of inertial frames suffice. In consequence of Einstein's addition law for velocities, which follows from the Lorentz transformation, a certain universal velocity cannot be exceeded. Only after having recognized the existence of this finite limiting velocity, is the latter identified with the speed of light. The kinematical consequences of the Lorentz transformation and the often discussed "paradoxes" are given a detailed treatment by way of examples in Section 2.5. Appropriate to the content of special relativity is the covariant formulation of physical laws in terms of relations between tensorial entities. Chapter 3 serves as an introduction to tensor calculus. The concept of a tensor field is introduced without restriction to linear transformations, and hence this chapter will prepare the student for the more general mathematical concepts used in general relativity. Concerning the notation it should be mentioned that three-dimensional vectors are written with an arrow on top of the character, whereas the components of four-vectors and four-tensors respectively, are denoted by greek indices. When studying Chapter 4 the reader will become familiar with the covariant formulation of relativity theory in Minkowski space. In this chapter the different pieces of the full Lorentz group and also the geometrical representation of the Lorentz transformation are discussed. Chapter 5 contains the relativistic formulation of classical mechanics. Special attention is given to the equivalence of mass and energy, illuminating this fundamental result by several examples. The relativistic invariant Lagrangian allows for a convenient derivation of the conservation laws. Energy-momentum conservation is exemplified by a variety of different processes, such as decay, creation, and scattering of particles. The attempt to formulate the dynamics of a system of interacting relativistic particles leads quite naturally to the concept of a physical field as the convenient means for a causal propagation of physical effects, i.e. interactions. As the most promi-

next example of a relativistic field theory, electrodynamics in its covariant formulation is treated in Chapter 6. A brief derivation of the fundamental Noether theorem is given, which shows how the conservation laws follow from the underlying symmetry transformations. In our case the symmetrical energy-momentum tensor of the electromagnetic field may be derived via Noether's theorem, thus avoiding the ad hoc and often used symmetrization procedure. In the subsequent Chapter 7 the fundamentals of relativistic hydrodynamics are presented, which are important for various topical applications in nuclear physics as well as in astrophysics. Finally, the last chapter contains a discussion regarding the limits of validity of special relativity theory, and it ends with a glimpse of the essential features of Einstein's gravitation theory, i.e. the theory of general relativity. More about the coverage of this book can be gleaned from the Table of Contents.

We quote a number of bibliographical data so as to guide the reader to the specialized literature which will offer most profitable and interesting further reading. After studying this text, he should be able to better understand the materials presented in journals. The problems given in the appendix are meant to stimulate further thought. At the end of the book the reader also finds a tabulation of more recent experiments testing the theory of special relativity.

I want to thank all readers of the German edition who called my attention to possible improvements. Special thanks are due to Professor Herbert Pfister (Tübingen), whose detailed comments proved most helpful. I also take the opportunity to thank my esteemed teacher, Professor Friedrich Hund (Göttingen), for his valuable inspirations.

I further want to thank Mrs. G. Boffo for the preparation of the manuscript for the printer, including the figures and the formulae, and Mrs. E. Martens for typing the footnotes.

Finally, I thank both my daughters, Ullinca and Tine, for their help rendered, especially for drawing the vignettes at the chapter endings.