INTRODUCTION

In this book we study the physical foundations of our contemporary view of space and time. We also discuss consequences of the established spatial-temporal symmetry transformations. These symmetries, expressed via the Lorentz- or Poincaré group, are universal i.e., they apply to all physical systems and processes. Hence, it would appear necessary to study all branches of physics in regard to their behaviour relative to the Lorentz group. In this book we will focus on the following special areas of classical physics: relativistic mechanics of a mass point, electrodynamics as an example of a relativistic field theory, and finally, the basic equations of relativistic fluid dynamics.

The term "theory of relativity" is not a fortunate one, inasmuch as it paraphrases the essence of the theory in a rather negative manner, thereby giving rise to several misunderstandings. The terminology originated from the fundamental "relativity principle", formulated at the beginning of this century by Poincaré and Einstein. This principle became the foundation for the development of new ideas about space and time. It made it possible to refute the notion of an absolute non-moving "Ether", a concept that has been introduced earlier, in analogy to the theory of the elastic phenomena, in order to serve as a "medium" in which optical and electromagnetic phenomena take place. At that time, one attempted to explain all phenomena by some mechanical theory and in this framework one concluded that it should be possible to establish motion relative to an ether at absolute rest. This conception contradicted the fact (known already to Galileo (1564-1642) and Huygens (1629-1695)) that, within the framework of mechanics, only relative velocities can be measured between bodies in uniform motion. (This statement is the Galilean principle of relativity for mechanics.) The hypothesized existence of an ether at rest was eventually refuted by compelling experimental findings. It turned out that even very sensitive experiments related to electromagnetic processes (such as the Michelson-Morley experiment in 1887) could not indicate the presence of an absolute frame of reference at rest. In electromagnetism, just as in mechanics, one can observe only relative motion. This insight is formalized in the "relativity principle", annunciated in the writings of Poincaré, and formulated more consistently and deeply by Einstein as an universal law. Joining it with the additional "principle of constant light velocity", in his 1905 work Einstein developed these elements into the foundations of the theory of special relativity.

However, the essence of relativity theory is not so much the "relativization" of concepts such as space and time, but rather the insight that the laws of nature are independent of the choice of one or another frame of reference provided these are in uniform relative motion to each other. The decisive statement of the theory is that natural phenomena are invariant against the change of a frame of reference, provided this change is in accord with the transformations of the Lorentz group. This maxim clarifies to what extent it is possible to make absolute physical statements (i.e. statements independent from the frame of reference). Invariance with respect to the Lorentz group implies certain structural features of physical laws. Thus, the relativity principle may be looked upon as an organizing ingredient of nature's laws.