

THE PRINCIPLE OF RELATIVITY

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The principle of relativity by E. Cunningham

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E. CUNNINGHAM

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by

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PREFACE

THE controversial note which has been characteristic of discussions in respect of the Principle of Relativity has prevented the significance of the principle from being seen in its proper proportions and in its relation to general physical theory. On the one hand, there have been those who have magnified its importance, and assigned to it an unduly revolutionary power, while on the other hand, there are those who have scoffed at it as fantastic and reared on the most slender of physical bases. It has therefore seemed desirable in the first part of this book to outline the way in which the Principle of Relativity grew out of electrical theory, so that it might be made clear that there is a real place for it as a hypothesis supplementary to and independent of electrical theory owing to the limitations to which that theory is subject.

It is hoped that by drawing a clear distinction between the 'mode of measurement,' and the 'nature' of space and time, the author will escape from the charge of venturing unduly upon debatable metaphysical questions.

In the Second Part an attempt has been made to present in a simple form the more attractive of the two mathematical methods devised by Minkowski for the purpose of putting in evidence the relative nature of electrical and other phenomena.

The Third Part seeks to indicate some of the most fundamental points in which mechanical theory needs modification if the principle is accepted as universal. It has not been thought advisable to give an account of the purely formal and rather

academic developments of special branches of mechanics such as hydromechanics, and elasticity, as these might tend to divert attention from the bearing of the principle on what are generally classified as the fundamental concepts. Some account of these is given by M. Laue in the second edition of his book, *Das Relativitätsprinzip*, Braunschweig, 1913. No attempt has been made to present the highly speculative attempt of Einstein at a generalization of the principle in connection with a physical theory of gravitation.

Throughout the intention has been as far as possible to consider those aspects of the principle which bear directly on practical physical questions. The mathematical part has been compressed to as small a compass as is consistent with furnishing sufficient apparatus for a systematic consideration of the problems suggested.

In the preparation of the book the author has received great help from Mr H. R. Hassé, who read the whole of the manuscript and made many suggestions for its improvement, besides reading the proofs of nearly the whole work. Mr R. W. James has also given valuable assistance in reading both manuscript and proofs. Especially would the author wish to acknowledge his debt to Sir Joseph Larmor, both personally and through his published works, for much stimulus and encouragement in the study of theoretical physics, and for valuable criticism of the earlier part of this book.

To the staff of the Cambridge University Press for care and courtesy in the work of printing the author is most grateful.

E. C.

CAMBRIDGE,
June 1914.

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PART I

THE PRINCIPLE OF RELATIVITY IN RELATION TO GENERAL PHYSICAL THEORY

CHAPTER I

THE RELATIVITY OF NEWTONIAN DYNAMICS

The scheme of dynamics formulated by Newton leaves undetermined the velocity of any particular particle of a body; or, what is the same thing, the frame of reference postulated as the background of dynamics is not unique, but is only determinate as one of an infinite group of which any one has a constant velocity of translation relative to any other. But while the differences only of the velocities of translation of particles are uniquely defined, the angular velocity of a single body is a quantity as to which dynamics leaves no ambiguity in definition.

A characteristic of the Newtonian conception of space is that an ideal rigid body always has the same volume and shape whatever its motion. There is no ambiguity in the meaning of the measurements of lengths and intervals of time. Also there is no ambiguity in the measurement of *mass* and *forces*. Whatever frame of reference is used these have the same value. Not so, however, with *energy* and *momentum*.

The assumption of the relativity of the phenomena, together with the assumption of the law of the conservation of energy, leads to the law of conservation of momentum Pages 1—10

CHAPTER II

THE DEVELOPMENT OF THE CONCEPT OF THE AETHER

The electric and luminiferous aether was first conceived as a species of fluid, another kind of matter which could be displaced by ordinary matter. This was gradually displaced by the conception of an immovable medium permeating all matter and unmoved by it; this in spite of the failure of all experiments to detect or determine the velocity of matter relative to it (Arago, Michelson and Morley, etc.). But explanations had to be devised to explain the failure of these experiments, and this raised questions as to the part which electrical phenomena play in the constitution of matter (FitzGerald-Lorentz contraction hypothesis). 11—22

CHAPTER III

THE ELECTRON THEORY

The attempts which have been made to explain the constitution of matter on purely electromagnetic lines all break down at some point. The schemes of electromagnetic equations have always to be supplemented by some kinematic or quasi-mechanical assumption, such as, for example, an assumption as to the configuration of an electron. The frame of reference which is postulated in the schemes of equations suggested has no *a priori* justification, its uniqueness or otherwise has, as in the case of the Newtonian frame of reference, to be established by reference to experiment. So far experiment has given no indication of a unique standard of rest or motion relative to the aether, which is nothing more than the frame of reference objectively conceived 23—30

CHAPTER IV

CORRELATION OF STATIONARY AND MOVING SYSTEMS

Since the frame of reference of the electron theory is not experimentally unique, the same body may be conceived by different persons as having different velocities. In the region of phenomena, as an accurate description of which the theory is complete, a correlation can be set up between the physical properties of the system in the two different states of motion in such a way that exactly the same equations are descriptive of the sequences in the two cases, the two frames of reference having relative to one another a constant velocity. But the correlation involves a difference between the measures of space and time in the two systems, the configuration of a body being estimated differently, and simultaneous events in one system being not simultaneous in the other. Nevertheless as far as the two systems equally well describe the phenomena, neither can be preferred to the other as the true description. Any assumption of a unique aether is thus from this point of view unjustified.

But the experimental failures to determine a unique aether extend into regions where the electron theory is by no means sufficient as an explanation, e.g. the optical properties of solid bodies, the conductivity of metals, the rigidity of the sandstone and pine of Michelson and Morley's experiments. We are therefore tempted to examine the consequences of the general assumption that physical phenomena will never discriminate between the various frames of reference permitted by the electron theory 31—41