INTRODUCTORY REMARKS TO THE ENGLISH EDITION

Since ancient times the question of the nature of geometry has been a decisive problem for any theory of knowledge. The principles of geometry, e.g., Euclid's axioms, seem to possess two characteristics which are not easily reconciled. On the one hand, they appear as immediately evident and therefore to hold with necessity. On the other hand, their validity is not purely logical but factual; in technical terms, they are not analytic but synthetic. This is shown by the fact that, on the basis of certain measurements of angles and lengths of physical bodies the results of other measurements can be predicted. Kant boldly accepted the conjunction of both characteristics: from the apparently necessary validity of the principles of geometry he concluded that their knowledge is *a priori* (i.e., independent of experience) although they are synthetic. When mathematicians constructed about a hundred years ago systems of non-Euclidean geometries, a controversy arose about the method of determining which of the systems, one Euclidean and infinitely many non-Euclidean, holds for the space of physics. Gauss was the first to suggest that the determination should be made by physical measurements. But the great majority of philosophers throughout the last century maintained the Kantian doctrine that geometry is independent of experience.

At the beginning of our century Poincaré pointed out the following new aspect of the situation. No matter what observational facts are found, the physicist is free to ascribe to physical space any one of the mathematically possible geometrical structures, provided he makes suitable adjustments in the laws of mechanics and optics and consequently in the rules for measuring length. This was an important insight. But Poincaré went further and asserted that physicists would always choose the Euclidean structure because of its simplicity. History refuted this prediction only a few years later, when Einstein used a certain non-Euclidean geometry in his general theory of relativity. Hereby he obtained a considerable gain in simplicity for the total system of physics in spite of the loss in simplicity for geometry.

Introductory Remarks to the English Edition

Through this development it has become clear that the situation concerning the nature of geometry is as follows. It is necessary to distinguish between pure or mathematical geometry and physical geometry. The statements of pure geometry hold logically, but they deal only with abstract structures and say nothing about physical space. Physical geometry describes the structure of physical space; it is a part of physics. The validity of its statements is to be established empirically—as it has to be in any other part of physics—after rules for measuring the magnitudes involved, especially length, have been stated. (In Kantian terminology, mathematical geometry holds indeed *a priori,* as Kant asserted, but only because it is analytic. Physical geometry is indeed synthetic; but it is based on experience and hence does not hold *a priori.* In neither of the two branches of science which are called "geometry" do synthetic judgments *a priori* occur. Thus Kant's doctrine must be abandoned.)

In physical geometry, there are two possible procedures for establishing a theory of physical space. First, the physicist may freely choose the rules for measuring length. After this choice is made, the question of the geometrical structure of physical space becomes empirical; it is to be answered on the basis of the results of experiments. Alternatively, the physicist may freely choose the structure of physical space; but then he must adjust the rules of measurement in view of the observational facts. (Although Poincaré emphasized the second way, he also saw the first clearly.This point seems to be overlooked by those philosophers, among them Reichenbach, who regard Poincaré's view on geometry as non-empiricist and purely conventionalist.)

The view just outlined concerning the nature of geometry in physics stresses, on the one hand, the empirical character of physical geometry and, on the other hand, recognizes the important function of conventions. This view was developed in the twenties of our century by those philosophers who studied the logical and methodological problems connected with the theory of relativity, among them Schlick, Reichenbach, and myself. The first comprehensive and systematic representation of this conception was given by Reichenbach in 1928 in his *Philosophie der Raum-Zeit-Lehre* (the original of the present translation). This work was an important landmark in the development of the empiricist conception of geometry. In my judgment it is still the best book in the field. Therefore the appearance of an English edition is to be highly welcomed; it satisfies a definite need, all the more since the German original is out of print.

Introductory Remarks to the English Edition

The book deals with the problems of the foundations of geometry and also of the theory of time, closely connected with that of space by Einstein's conception-in all their various aspects, e.g., the relations between theory and observations, connected by coordinative definitions, the relations between topological and metrical properties of space, and also the psychological problem of the possibility of a visual intuition of non-Euclidean structures.

Of the many fruitful ideas which Reichenbach contributed to the development of this philosophical theory, I will mention only one, which seems to me of great interest for the methodology of physics but which has so far not found the attention it deserves. This is the principle of the elimination of universal forces. Reichenbach calls those physical forces universal which affect all substances in the same way and against which no isolating walls can be built. Let T be the form of Einstein's theory which uses that particular non-Euclidean structure of space which Einstein proposes; in T there are no universal forces. According to our above discussion, T can be transformed into another form T' which is physically equivalent with T in the sense of yielding the same observable results, but uses a different geometrical structure. Reichenbach shows that any such theory T' has to assume that our measuring rods undergo contractions or expansions depending merely upon their positions in space, and hence has to introduce universal forces to account for these changes. Reichenbach proposes to accept as a general methodological principle that we choose that form of a theory among physically equivalent forms (or, in other words, that definition of "rigid body" or "measuring standard") with respect to which all universal forces disappear. If this principle is accepted, the arbitrariness in the choice of a measuring procedure is avoided and the question of the geometrical structure of physical space has a unique answer, to be determined by physical measurements.

Even more outstanding than the contributions of detail in this book is the spirit in which it was written. The constant careful attention to scientifically established facts and to the content of the scientific hypotheses to be analyzed and logically reconstructed, the exact formulation of the philosophical results, and the clear and cogent presentation of the arguments supporting them, make this work a model of scientific thinking in philosophy.

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