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1. On the Principle of Relativity (1914)

Vossische Zeitung (26 April 1914), Morgen-Ausgabe, no. 2, pp. [1–2] of 8. [*Collected Papers* Vol. 6, Doc. 1].

By April 1914, Einstein had published two non-technical expositions of special relativity, and one journal article in which he touched on general relativity as well. This document is the first exposition to appear in a daily newspaper.

The editorial staff of the *Vossische Zeitung* has asked me to relate something about my field of work to readers. I gladly honor this request. Although a deeper understanding of the theory of relativity is hardly possible without considerable effort, it may still be appealing for the non-scientist to hear something about the methods and results of this new branch of theoretical research.

Even a cursory analysis of the processes we call motion already teaches us that we can perceive only the relative motion of things with respect to one another. We sit in a railway carriage and see (on the adjacent track) another carriage pass by. If we ignore the vibration of our carriage, we have no immediate means by which to decide whether the two carriages are moving "in reality." We find only that the relative position of the carriages changes over time. Even if we look at the telegraph poles alongside the track, nothing essential changes in this situation. For when we usually refer to telegraph poles (and the earth's surface) as "at rest" and every object moving relative to them as "in motion," we merely use a customary and handy expression without deeper meaning. An observer in a "moving" railway carriage will not come into conflict with his perceptions if he states that the carriage is at rest and the ground and telegraph poles are in motion.

Physicists have found over time that this characteristic of motion, to appear purely relative, is not merely attributable to primitive perception, but rather that one is justified to call any single thing "at rest" among a multitude of things that are in relative (uniform) motion with respect to one another. Let's think again of a uniformly moving carriage on a straight track. Let the windows be closed airtight, with no

light coming in; wheels and tracks are completely smooth. Inside the carriage is a physicist with all kinds of apparatuses imaginable. We do know all experiments done by this physicist would come out exactly the same if the carriage were not moving, or if it were moving at a different velocity, for that matter. This statement is essentially what physicists call the "principle of relativity." One can generally phrase this principle as: "The laws of nature perceived by an observer are *independent* of his state of motion."

This statement sounds harmless and self-evident. It would not have excited anybody were it not for the fact that the laws of the propagation of light, which have emerged from the recent development in electrodynamics, seem incompatible with this principle. The phenomena of the optics of moving bodies have led to the interpretation that light always propagates with the same velocity in empty space, irrespective of the state of motion of the light source. Yet, this result seems to contradict the aforementioned principle of relativity. After all, when a beam of light travels with a stated velocity relative to one observer, then a second observer who is himself traveling in the direction of the propagation of the light beam, so it seems, should find the light beam propagating at a lesser velocity than the first observer would. If this were indeed true, then the law of light propagation in a vacuum would not be the same for two observers in relative uniform motion to each other, in contradiction to the principle of relativity stated above.

This is where the theory of relativity comes in. This theory shows that the law of constancy of light propagation in a vacuum can be satisfied simultaneously for two observers in relative motion to each other, such that the same beam of light shows the same velocity to both.

At first glance, the possibility for such a paradoxical interpretation can be understood through a more detailed analysis of the physical meaning of spatial and temporal statements. Recognizing the relativity of the concept of simultaneity is of special importance to this question. Before the theory of relativity, it was believed that the statement "two events happening at two different places are simultaneous" had a clear meaning—clear without a special need to define the concept of simultaneity. A more detailed investigation that did not skirt the issue of defining simultaneity showed, however, that the simultaneity of two events is not absolute, but instead can only be defined relative to one observer of a given state of motion. It turns out that two events

simultaneous with respect to one observer are, in general, not simultaneous with respect to a second observer moving relative to the first one. This signifies a fundamental change in our concept of time. (This is the most important and most controversial theorem of the new theory of relativity. It is impossible to enter here into an in-depth discussion of the epistemological and scientific philosophical assumptions and consequences evolving from this basic principle).[1]

By combining the principle of relativity with the results of the constancy of the speed of light in vacuum, one arrives at what is today called "relativity theory" in a purely deductive manner. This theory has already proven itself as an aid for the theoretical deduction of the laws of nature. Its significance lies in the fact it provides conditions every general law of nature must satisfy, for the theory teaches that events in nature are such that the laws do not depend on the state of motion of the observer to whom the events are related spatially and temporally.

Two of the major results of the theory of relativity should be mentioned here, as they are also of interest to the layman. First: the hypothesis of the existence of a space-filling medium for light propagation, the so-called light-ether, must be abandoned. According to this theory, light no longer appears as a state of motion of an unknown carrier, but rather as a physical structure with a physical existence of its own. Second: the theory establishes that the inertia of a body is not an absolutely unchanging constant, but instead grows with the energy content. The important conservation theorems of mass and energy melt into a single theorem; the energy of a body also determines its mass.

Is the theory of relativity sketched above basically complete, or is it only a first step in a continuing development? Physicists who value the theory of relativity still hold differing opinions on this question. Nevertheless, weighty arguments speak for the second alternative. We have stated above that the laws of nature are the same for a "uniformly moving" observer as they are for one "at rest." This means an observer cannot find criteria that would allow him to decide if he is at rest or in a state of uniform motion. "At rest" and "in uniform motion" are physically

[1] Those who want to familiarize themselves with a more detailed substantiation and justification can find sufficient instruction—without difficult mathematical derivations—in E. Cohn's pamphlet, "Physikalisches über Raum und Zeit,"[a] and in an essay by Jos. Petzoldt, "Die Relativitästheorie der Physik,"[b] in the most recent issue of the *Zeitschrift für positivistische Philosophie*.

equivalent. This raises the question whether the principle of relativity is limited to uniform motion. Could the laws of nature not be such that they are the same for two observers who are in nonuniform motion relative to each other? Recently, it has turned out such an extension of relativity theory can be carried out and leads to a general theory of gravitation that contains the Newtonian theory as a first approximation. According to this theory, light rays suffer a curvature in a gravitational field; though minute, it is just within the range of astronomical measurement. The future will teach us whether this generalized relativity theory, which is very satisfying from an epistemological aspect, conforms to reality.

Editorial Notes

[a] Cohn 1913.

[b] Petzolt 1914.

2. Inaugural Lecture at the Prussian Academy of Sciences (1914)

Königlich Preußische Akademie der Wissenschaften. Berlin: Sitzungsberichte (1914), pp. 739–742. [*Collected Papers* Vol. 6, Doc. 3].

This lecture was delivered on 2 July 1914 to the Prussian Academy of Sciences in Berlin. Einstein had been appointed a member of the Academy in November 1913 and had moved from Zurich to Berlin only a few weeks before the lecture. The text contains an early discussion of the deductive character of relativity, which he contrasts with other physical theories that seek to find foundational principles inductively.

Most honored colleagues!

Please accept, first, my heartfelt gratitude for the greatest favor you could have bestowed upon a person of my kind. By appointing me to your Academy, you have allowed me to devote myself wholly to

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