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Review Article

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Teacher's Discomfort with the Theory of Relativity

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ABSTRACT

This essay critically examines how a theory often perceived as incomprehensible can nevertheless develop into a foundation of scientific practice with immense popularity. It first analyzes several unresolved problems of understanding from school curricula before suggesting a path to clarification that has not yet been explored in science studies.

Imagine you, as a schoolteacher, are tasked with preparing a lecture on Einstein's theory of relativity. Naturally, you have no laboratory or suitable experimental equipment at your disposal, nor a scientific library, but at best a few textbooks and the local antiquarian bookshop with its selection of inexpensive old physics books. Furthermore, you still vividly recall numerous post-lesson conversations on the train ride home, such as discussions with an electrical engineer from Mercedes-Benz and an equally critical architect from the Stuttgart Regional Council, which can certainly put a physics teacher's pedagogical skills to the test.

Especially when you're aware that, according to Austrian textbook author Roman Sexl, there are only twelve people in the world who understand Einstein's theory of relativity. Imagine that!

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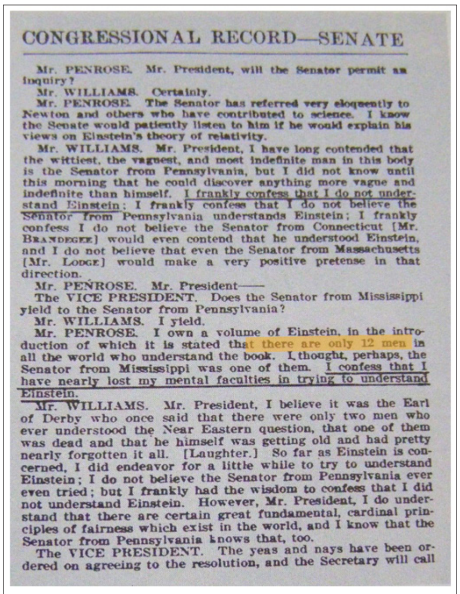

CONGRESSIONAL RECORD—SENATE

Mr. PENROSE. Mr. President, will the Senator permit an inquiry?

Mr. WILLIAMS. Certainly.

Mr. PENROSE. The Senator has referred very eloquently to Newton and others who have contributed to science. I know the Senate would patiently listen to him if he would explain his views on Einstein's theory of relativity.

Mr. WILLIAMS. Mr. President, I have long contended that the wittiest, the vaguest, and most indefinite man in this body is the Senator from Pennsylvania, but I did not know until this morning that he could discover anything more vague and indefinite than himself. I frankly confess that I do not understand Einstein; I frankly confess that I do not believe the Senator from Pennsylvania understands Einstein; I frankly confess I do not believe the Senator from Connecticut [Mr. Brandegee] would even contend that he understood Einstein, and I do not believe that even the Senator from Massachusetts [Mr. Lodge] would make a very positive pretense in that direction.

Mr. PENROSE. Mr. President——

The VICE PRESIDENT. Does the Senator from Mississippi yield to the Senator from Pennsylvania?

Mr. WILLIAMS. I yield.

Mr. PENROSE. I own a volume of Einstein, in the introduction of which it is stated that there are only 12 men in all the world who understand the book. I thought, perhaps, the Senator from Mississippi was one of them. I confess that I have nearly lost my mental faculties in trying to understand Einstein.

Mr. WILLIAMS. Mr. President, I believe it was the Earl of Derby who once said that there were only two men who ever understood the Near Eastern question, that one of them was dead and that he himself was getting old and had pretty nearly forgotten it all. [Laughter.] So far as Einstein is concerned, I did endeavor for a little while to try to understand Einstein; I do not believe the Senator from Pennsylvania ever even tried; but I frankly had the wisdom to confess that I did not understand Einstein. However, Mr. President, I do understand that there are certain great fundamental, cardinal principles of fairness which exist in the world, and I know that the Senator from Pennsylvania knows that, too.

The VICE PRESIDENT. The yeas and nays have been ordered on agreeing to the resolution, and the Secretary will call

Figure 1: Sexl-Raab-Streeruwitz: Matter in Space and Time Volume 3, Diesterweg 1980

Based on this, you as a teacher will then analyze where you failed to explain the theory of relativity in your lessons and discussions. Please now follow me to the intellectual hurdles that stand in the way of a didactic clarification of the theory of relativity. A brief outline of the questions that repeatedly arise, but are never plausibly answered, should suffice here.

Speed of a Science Fiction Rocket

Figure 2: Badische Neueste News from December 30, 2023

In physics class, following the introduction to kinematics, the question arises as to the speed of a rocket traveling through space for one year at an acceleration of 1 g (= 9.81 N/kg). The calculated result could pose a problem for understanding the theory of relativity.

The questionable term

Closely related to the speed of light limit is the question of what meaning the mathematical term "c + v" should have in the formulas of relativity theory.

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die ... tion $u = u' + v$ der klassischen Physik übergeht. Das Additionstheorem erfüllt, wie es sein muß, da... von der Konstanz der Lichtgeschwindigkeit. S... $u' = c$ ein, so folgt $u = c$, wie folgende Rechnung...

$$u = \frac{c+v}{1 + \frac{c\,v}{c^2}} = \frac{c+v}{\frac{c+v}{c}} = c\,.$$

1964 wurde im europäischen Kernforschun... CERN die Formel überprüft, indem die von sehr... Pi-Mesonen in Vorausrichtung ausgesandte Stra... messen wurde. Pi-Mesonen sind Elementartei... unter Aussendung von Gammastrahlung zerfall... Experiment hatten die Pi-Mesonen eine Geschw...

Figure 3: Metzler textbook Physics Stuttgart 1988, page 349

Within the logic of relativity, "c + v" represents an undefined expression. Although no reliable calculation can be based on something undefined, the term repeatedly appears in relativity theory. The question seems even more fundamental with regard to the necessary tolerance specifications in the experimental determination of the speed of light. This is because, formally, it also involves the additive addition of a velocity. The topic becomes particularly relevant when considering the speed at which two photons move toward each other. Journalist Kurt Rudzinski received contradictory answers to a corresponding question from Nobel laureates Born and Dirac (FAZ, October 6, 1959).

Conflict with Algebra

Even elementary school children can correctly state the answer to the problem 3 + 1 = 4; they can count it on one hand. But can Nobel laureates in modern physics also solve this problem? I would like to present the problem the Nobel laureates face: It is mathematically permissible to multiply both sides of the equation by 100,000 km/s. This should result in 300,000 km/s + 100,000 km/s = 400,000 km/s. However, since such a result is impossible according to the theory of relativity, there must be an error in the algebraic representation. This error can only lie in the reality-oriented assumption that 3 + 1 = 4. And that is the difficulty that the Nobel laureates cannot overcome.

Is the Clock Paradox a Calculation Error?

The most well-known relativistic effect is probably the clock paradox, according to which a moving clock A must lag behind a clock B. Conversely, clock B can also be considered to be moving and therefore lagging behind clock A. This means that each clock lags behind the other by the same amount! The inevitable consequence of the theory of relativity was questioned even in its early days (see Wolters, Gereon: Mach I, Mach II, Einstein and the Theory of Relativity, de Gruyter: Berlin/New York 1987, p. 163). Algebraic analysis points to a calculation error in the theory as the origin of the effect; we will consider the illustration in a physics textbook widely used in schools and universities:

(R 41.7) $$\boxed{\Delta t' = \frac{\Delta t}{\sqrt{1-\beta^2}} \geqq \Delta t}$$

Umgekehrt ergibt sich aber auch

(R 41.8) $$\boxed{\Delta t = \frac{\Delta t'}{\sqrt{1-\beta^2}} \geqq \Delta t'}$$

Figure 3: Kuchling, Horst: Pocketbook of Physics, 14th edition; Leipzig, Cologne: Fachbuchverlag, 1994, p. 587

Those with mathematical expertise will immediately recognize that this is not a paradox, but an antinomy. Within the same theory, the formulas exhibit the structure A = B / C and B = A / C – a devastating finding for the formulas of relativity theory!

Historical Context

Figure 4: Grimsehl, Ernst: Textbook of Physics; Leipzig and Berlin: Teubner 1912

The theory of relativity was first mentioned in a school textbook in 1912, in the physics textbook written by the Hamburg school principal Ernst Grimsehl.

Since then, chapters on the theory of relativity have become standard in every physics textbook for secondary schools. This success and popularity are incomprehensible given the difficulties encountered in teaching the theory of relativity, as long as one remains within the framework of the usual accounts of its development (e.g., Hermann, Armin: Einstein, 1994; Holton, Gerald: Science and Antiscience, 2000; or Isaacson, Walter: Einstein – His Life and Universe, 2007). Since the conventional accounts do not solve the puzzle, indeed, do not even recognize it, I must employ a different method to investigate the truth. I begin by examining the circle of people who supported the theory of relativity and promoted its dissemination. The names Hilbert, Hurwitz, von Laue, Minkowski, Planck, Sommerfeld, Voigt, and Volkmann come to light. Their careers show a sometimes-significant connection to Protestantism, which, particularly in imperial Berlin, had developed into state Protestantism. We recognize the religious allusion in the statement quoted at the beginning, that only 12 men (the number of apostles!) understand the theory of relativity. However, there are hardly any Catholics or Jews among the promoters of the early theory of relativity in the Western world. – Another commonality among these scientists is striking: they regularly had a personal connection to the prize-winning mathematician Ferdinand Lindemann in Munich, primarily as his students or former collaborators and colleagues. Once we become aware of the now almost forgotten Ferdinand Lindemann, later Ferdinand Ritter von Lindemann, we soon encounter his work as a translator and editor of the writings of the Frenchman Henri Poincaré into German. Lindemann translated the book "La Science et l'Hypothèse," which is close to the circle of ideas of the positivist natural philosopher Ernst Mach in Vienna, into German. It was published in 1904 under the title "Wissenschaft und Hypothese" (Science and Hypothesis). Lindemann had added a substantial appendix of his own remarks to Poincaré's work, of which we will examine this one in particular:

97) S. 215. Dieser umgekehrte Weg (Ableitung der elektrischen Erscheinungen aus den optischen) hat mich seit langem beschäftigt; und ich habe denselben im Sommer 1902 in meinen Vorlesungen so weit durchgeführt, daß sich die wichtigsten Resultate der Elektrodynamik und des Magnetismus ergeben; ich hoffe eine Darstellung dieser Untersuchungen bald veröffentlichen zu können.

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What exactly is Ferdinand Lindemann ("Vanquisher of Pi!") describing here? Since the aforementioned investigations were intended for publication, one would expect to find a corresponding publication in the archives of university libraries under the author's name. In fact, it is nowhere to be found in the scientific periodicals from 1904 to 1908, and publication in the following years is unlikely. However, a publication containing the content described by Lindemann does appear in the Annalen der Physik (Annals of Physics), supervised by Max Planck, from September 26, 1905. It is titled "On the Electrodynamics of Moving Bodies" and lists Albert Einstein (born March 14) as the author. This paper forms the basis of the later, so famous "Einstein's Theory of Relativity."

This gives the impression that the theory of relativity may have originated from a clash of two intellectual worlds: the positivist world of Ernst Mach and Henri Poincaré on the one hand, and Prussian state Protestantism around Max Planck on the other. Caught in the middle is the mystical-mythological significance of the number Pi (3.14), which one repeatedly encounters when exploring the topic. But that is not physics; it is a story in itself, one that goes beyond the scope of this discussion.

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