How General Relativity Shaped Twentieth-Century Philosophy of Science

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Einstein in 1914

A Different Kind of Gravitational Wave

The publication of the general theory of relativity in the Winter of 1915 produced a significant disturbance in the field of philosophy of science, one whose effects are still being felt today.

Philosophy of science after 1915 is importantly different from what went before.

The Main Thesis

Much of the fine structure of early-twentieth century philosophy of science, both the core logical empiricist tradition and the tradition from Cassier to Weyl that Tom Ryckman dubs "critical idealism," was shaped in detail by the challenge posed by general relativity. Likewise for still other traditions and thinkers, including Émile Meyerson and Henri Bergson.

The challenge of general relativity touched on several points, including:

1. The logical structure and empirical interpretation of physical theory.
2. The ontology of physical theory.
3. The heuristics of scientific discovery.

The challenge of general relativity structered the argument space as one mainly pitting varieties of neo-Kantianism against what Moritz Schlick named the "new empiricism."

Moreover, Einstein was not merely the physicist whose work produced the challenge, he was, himself, one of the most important participants in the debates, eventually coming to dissent from both critical idealism and logical empiricism with a philosophy of science of his own that displays deep affinities with Pierre Duhem's underdeterminationist variety of conventionalism.

More Specifically

Mainstream logical empiricism of the 1920s and beyond held that theories are connected with experience and the world via "coordiinating" definitions that link individual primitive terms - think of the example of the infinitesimal metric interval - with corresponding definite experiences or structures in the world. This view assumes a principled distinction between analytic coordinating definitions and synthetic empirical propositions, and it confines the moment of convention in science to the choice of those coordinating definitions. On this view, given a choice of coordinating definitions, experience renders a definite verdict on the truth or falsity of each, individual empirical claim. This way of regarding the empirical interpretation of theories derives from Henri Poincaré's conventionalism about metrical geometry. It was preferred by many because it was throught to offer an especially strong response to Kantian critics of general relativity.

The chief dissent to this view, famously associated in later years with the "left-wing" logical empiricist, Otto Neurath, and the American philosopher, W.V.O. Quine, asserts that theories are tested only as wholes, there being no possible principled distinction between analytic definitions and synthetic empirical propositions, in consequence of which the moment of conventionality is distributed over the entire theory, entailing an in-principle underdetermination of theory choice by experiment. This view derives from the conventionalism of Pierre Duhem. And this was Einstein's view.

Two Narrative Lines

I will develop the main thesis by following two different but intersecting lines of development.

1. Point coincidences, “Eindeutigkeit,” and both the ontological commitments and empirical interpretation of general relativity.

2. Neo-Kantianism, Conventionalism, and the “New Empiricism.”

These two lines begin in December of 1915, at which point they somewhat diverge, only to intersect again in the mid-1920s.

Begin by Remembering Two Facts

Begin by Remembering Two Facts

First, even by the higher standards of his day, Einstein, our principal actor, was uncommonly well educated in philosophy, generally, and in the history and philosophy of science.

Einstein's Early Acquaintance with Philosophy

While a student at the ETH (1896-1900):

Ernst Mach. *Die Mechanik in ihrer Entwickelung historisch-kritisch dargestellt*. (1883; 3rd ed., 1897).
Ernst Mach. *Die Principien der Wärmelehre. Historisch-kritisch entwickelt*. (1896).
Arthur Schopenhauer. *Parerga und Paralapomena. Kleine Philosophische Schriften*. (1851).

Physikalisches Institut, ETH Zürich

Lectures by August Stadler (Student of Friedrich Albert Lange in Zurich; Ph.D. under the Marburg neo-Kantian, Hermann Cohen):

Sommersemester 1897 — Die Philosophie Kants
Wintersemester 1897 — Theorie des wissenschaftlichen Denkens ("obligatorisches Fach")

Friedrich Albert Lange. *Geschichte des Materialismus*. (1873-1875).
Eugen Dühring. *Kritische Geschichte der Principien der Mechanik*. (1887).
Ferdinand Rosenberger. *Isaac Newton und seine physikalischen Prinzipien*. (1895).

Einstein’s Early Acquaintance with Philosophy

Akademie Olympia (ca. 1903-1905)

Richard Avenarius. *Kritik der reinen Erfahrung*. (1888, 1890).
Richard Dedekind. *Was sind und was sollen die Zahlen?* (2nd ed. 1893).
David Hume. *A Treatise of Human Nature*. (1739; German trans. 1895; 2nd ed. 1904)
Ernst Mach. *Die Analyse der Empfindungen und das Verhältnis des Physischen zum Psychischen*. (2nd ed. 1900; 3rd enl. ed. 1902; 4th enl. ed. 1903).
John Stuart Mill. *A System of Logic*. (1872; German trans. 1877 and 1884-1887).
Karl Pearson. *The Grammar of Science*. (1900).
Henri Poincaré. *La science et l’hypothèse*. (1902; German trans. 1904).

The Olympia Academy, Bern, ca. 1904. From left: Conrad Habicht, Maurice Solovine, Albert Einstein.

Ernst Mach

Ernst Mach. *Die Mechanik in ihrer Entwickelung historisch-kritisch dargestellt*. (1883; 3rd ed., 1897).

Ernst Mach. *Die Principien der Wärmelehre. Historisch-kritisch entwickelt*. (1896).

Ernst Mach. *Die Analyse der Empfindungen und das Verhältnis des Physischen zum Psychischen*. (2nd ed. 1900; 3rd enl. ed. 1902; 4th enl. ed. 1903).

Ernst Mach (1838-1916)

Henri Poincaré

Henri Poincaré. *La science et l'hypothèse*. Paris: Ernest Flammarion, 1902.

Henri Poincaré. *Wissenschaft und Hypothese*. Ferdinand and Lisbeth Lindemann, trans. Leipzig: B. G. Teubner, 1904.

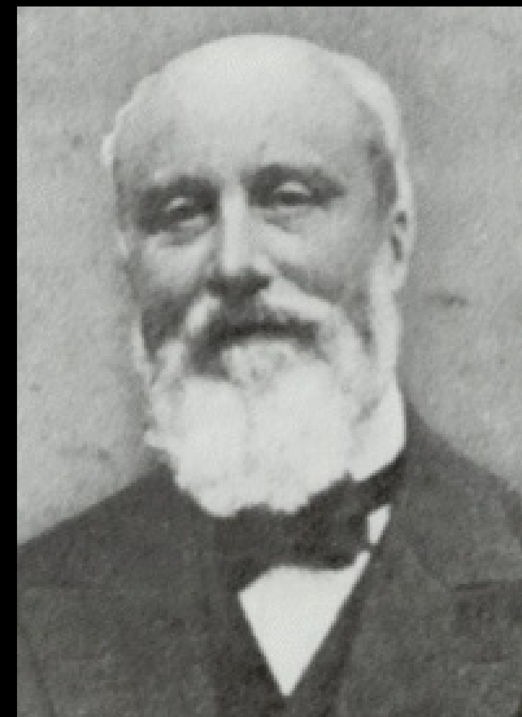
Henri Poincaré. *La valeur de la science*. Paris: Ernest Flammarion, 1905.

Henri Poincaré (1854-1912)

Pierre Duhem

Pierre Duhem. *La Théorie physique: son objet et sa structure*. Paris: Chevalier & Rivière.(1906).

Pierre Duhem. *Ziel und Struktur der physikalischen Theorien*. Friedrich Adler, trans. Foreward by Ernst Mach. Leipzig: Johann Ambrosius Barth. (1908).



Pierre Duhem (1861-1916)

Begin by Remembering Two Facts

Second, many of the major philosophers of science of the early twentieth century, and especially those in the logical empiricist tradition, began their careers by engaging the new science of general relativity.

Moritz Schlick

Ph.D. under Max Planck, Berlin, 1904
“Über die Reflexion des Lichtes in einer inhomogenen Schicht.”

1904-1907, Further studies in physics, Göttingen, Heidelberg, and Berlin
1907-1910, Studies in psychology and philosophy, University of Zurich
1911-1921, Privatdozent in philosophy, Rostock

“Die philosophische Bedeutung des Relativitäts-prinzips.” *Zeitschrift für Philosophie und philosophische Kritik* 159 (1915), 129-175.

Raum und Zeit in den gegenwärtigen Physik. Zur Einführung in das Verständnis der allgemeinen Relativitäts-theorie. Berlin: Julius Springer, 1917.

1921, Ausserordentlicher Professor, Rostock
1921-1922, Ordentlicher Professor, Kiel
1922-1936, Lehrstuhl für Naturphilosophie (Philosophie der induktiven Wissenschaften), Vienna (Successor of Mach und Boltzmann)

Moritz Schlick (1882-1936)

Hans Reichenbach

Ph.D. Erlangen, under Paul Hensel and Max Noether, 1915
"Der Begriff der Wahrscheinlichkeit für die mathematische Darstellung der Wirklichkeit"

Audits Einstein's Berlin lectures on general relativity, 1917-1920

Relativitätstheorie und Erkenntnis Apriori. Berlin: Julius Springer, 1920.

Privatdozent, Technische Hochschule Stuttgart, 1920-1926

Axiomatik der relativistischen Raum-Zeit-Lehre. Braunschweig: Friedrich Vieweg und Sohn, 1924.

Ausserordentlicher Professor, Physics, University of Berlin, 1926-1933

Philosophie der Raum-Zeit-Lehre. Berlin and Leipzig: Walter de Gruyter, 1928.

Chair, Department of Philosophy, University of Istanbul, 1933-1938

Department of Philosophy, UCLA, 1938-1953

Hans Reichenbach (1891-1953)

Rudolf Carnap

Ph.D. Jena, under Bruno Bauch, 1921, "Der Raum"

"Über die Abhängigkeit der Eigenschaften des Raumes von denen der Zeit." *Kant-Studien* 30 (1925), 331- 345.

Physikalische Begriffsbildung. Wissen und Wirken. Einzelschriften zu den Grundfragen des Erkennens und Schaffens. Emil Ungerer, ed., vol. 39. Karlsruhe: G. Braun, 1926.

Habilitation, University of Vienna, 1926
Der logische Aufbau der Welt

Privatdozent, University of Vienna, 1926-1931

Professur für Naturphilosophie, German University of Prague, 1931-1935

Department of Philosophy, University of Chicago, 1936-1952

Department of Philosophy, Princeton University, 1952-1954

Department of Philosophy, UCLA, 1934-1961

Rudolf Carnap (1891-1970)

The Path to General Relativity

The Path to General Relativity

Albert Einstein and Marcel Grossmann. *Entwurf einer verallgemeinerten Relativitätstheorie und einer Theorie der Gravitation. I. Physikalischer Teil von Albert Einstein. II. Mathematischer Teil von Marcel Grossmann.* Leipzig and Berlin: B.G. Teubner, 1913. Reprinted with added "Bemerkungen," *Zeitschrift für Mathematik und Physik* 62 (1914), 225-261.

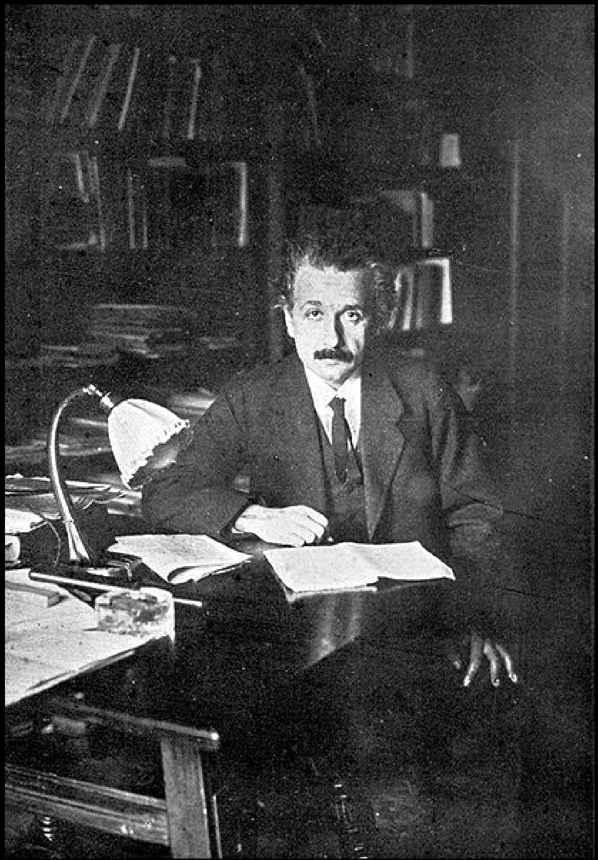
Albert Einstein and Marcel Grossmann. "Kovarianzeigenschaften der Feldgleichungen der auf die verallgemeinerte Relativitätstheorie gegründeten Gravitationstheorie." *Zeitschrift für Mathematik und Physik* 63 (1914), 215-225.

Albert Einstein. "Die formale Grundlage der allgemeinen Relativitätstheorie." *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1914), 1030-1085.

Einstein on the "Hole" Argument

Events [das Geschehen] *in the gravitational field cannot be determined uniquely* [eindeutig festgelegt] *by means of generally covariant differential equations for the gravitational field*. If we demand, therefore, that the course of events [der Ablauf des Geschehens] in the gravitational field be completely determined [vollständig bestimmt] by means of the laws that are to be established, then we are obliged to restrict the choice of the coordinate system.

Albert Einstein. "Die formale Grundlage der allgemeinen Relativitätstheorie." *Königlich Preussisch Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1914), 1030-1085.



Albert Einstein (1879-1955)

The Path to General Relativity

Albert Einstein. “Zur allgemeinen Relativitätstheorie.” *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1915), 778-786, 799-801.

Albert Einstein. “Erklärung der Perihelbewegung des Merkur aus der allgemeinen Relativitäts-theorie.” *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1915), 831-839.

Albert Einstein. “Die Feldgleichungen der Gravitation.” *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte:* (1915). 844-847.

Albert Einstein. “Die Grundlage der allgemeinen Relativitätstheorie.” *Annalen der Physik* 49 (1916), 769-822.

Moritz Schlick. "Die philosophische Bedeutung des Relativitätsprinzips." ***Zeitschrift für Philosophie und philosophische Kritik*** **159 (1915), 129-175.**

The totality of our scientific propositions, in word and formula, is in fact nothing else but a system of symbols *correlated* to the facts of reality; and that is equally certain, whether we declare reality to be a transcendent being or merely the totality and interconnection of the immediately "given." The system of symbols is called "true," however, if the correlation is completely univocal. Certain features of this symbol system are left to our arbitrary choice; we can select them in this way or that without damaging the univocal character of the correlation. It is therefore no contradiction, but lies, rather, in the nature of the matter, that under certain circumstances, several theories may be true at the same time, in that they achieve indeed a different, but each for itself completely univocal designation of the facts.

See also:

Moritz Schlick. "Das Wesen der Wahrheit nach der modernen Logik." *Vierteljahrsschrift für wissenschaftliche Philosophie und Soziologie* 34 (1910), 386-477.

Einstein to Schlick, 13 December 1915

Yesterday I received your essay and I have already studied it through completely. It is among the best that have until now been written about relativity. From the philosophical side, nothing at all appears to have been written on the subject that is nearly so clear. At the same time, you really have complete command of the subject. There is nothing in your exposition with which I find fault.

Moritz Schlick (1882-1936)

Narrative One

Point coincidences, “Eindeutigkeit,” and both the ontological commitments and empirical interpretation of general relativity.

Einstein on the “Point-Coincidence” Argument

Einstein to Paul Ehrenfest, 26 December 1915

In § 12 of my work of last year, everything is correct (in the first three paragraphs) up to that which is printed with emphasis at the end of the third paragraph. From the fact that the two systems $G(x)$ and $G'(x)$, referred to the same reference system [the same x], satisfy the conditions of the grav. field, no contradiction follows with the uniqueness of events [Eindeutigkeit des Geschehens]. That which was apparently compelling in these reflections founders immediately, if one considers that 1) the reference system signifies nothing real, 2) that the (simultaneous) realization of two different g-systems (or better, two different fields) in the same region of the continuum is impossible according to the nature of the theory.

In place of § 12, the following reflections must appear. The physically real in the world of events [Weltgeschehen] (in contrast to that which is dependent upon the choice of a reference system) consists *in spatio-temporal coincidences*.* Real are, e.g., the intersections of two different world lines, or the statement that they *do not* intersect. Those statements which refer to the physically real therefore do not founder on any univocal [eindeutige] coordinate transformation. If two systems of the $g_{\mu\nu}$ (or in general the variables employed in the description of the world) are so created that one can obtain the second from the first through mere space-time transformation, then they are completely equivalent [gleichbedeutend]. For they have all spatio-temporal point coincidences in common, i.e., everything that is observable.

These reflections show at the same time how natural the demand for general covariance is.

*) and in nothing else!

Albert Einstein. "Die Feldgleichungen der Gravitation." ***Königlich Preussische Akademie der Wissenschaften*** **(Berlin).** ***Sitzungsberichte*** **(1915), 844-847.**

The relativity postulate in its most general formulation, which turns the spacetime coordinates into physically meaningless parameters, leads with compelling necessity to a completely determinate theory of gravitation.

Einstein to Moritz Schlick, 14 December 1915

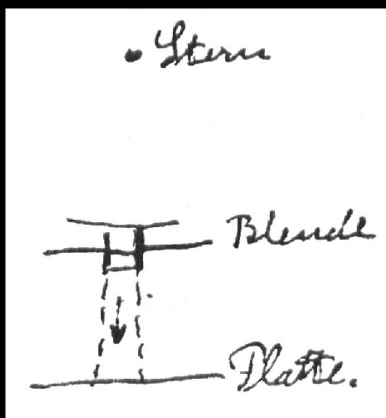
Time and space thereby lose the last vestige of physical reality.

Einstein to Michele Besso, 3 January 1916

In the *Lochbetrachtung*, everything was correct up to the final conclusion. There is no physical content in the existence of two different solutions $G(x)$ and $G'(x)$ with reference to the *same* coordinate system K. Attributing two different solutions to the same manifold is senseless, and the system K has, indeed, no physical reality. The following consideration takes the place of the *Lochbetrachtung*. From a physical point of view, nothing is *real* except the totality of spatiotemporal point coincidences. If, e.g., physical processes [das physikalische Geschehen] were to be built up solely out of the movements of material points, then the meetings of the points, i.e., the points of intersection of their world lines, would be the only reality, i.e., observable in principle. These points of intersection are naturally preserved under all transformations (and no new ones are added), if only certain uniqueness conditions [Eindeutigkeitsbedingungen] are maintained. Thus, it is most natural to demand of the laws that they do not determine *more* than the totality of the spatiotemporal coincidences. According to what has been said, this is already achieved by generally-covariant equations.

Einstein to Paul Ehrenfest, 25 January 1916

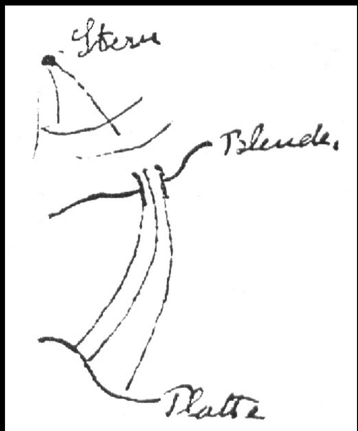
I cannot blame you for the fact that you have not yet understood the admissibility of generally-covariant equations, because I, myself, took so long to achieve clarity on this point. Your difficulty is rooted in your instinctively treating the reference system as something "real."



Your somewhat simplified example: You consider two solutions with the same boundary conditions at infinity, in which the coordinates of the star, the material point of the screen, and the plate are the same. You ask whether "the direction of the wave normal" at the screen always turns out the same. As soon as you speak of "the direction of the wave normal *at the screen*, you are treating this space with respect to the functions $g_{\mu\nu}$ as an infinitely small space. This and the determinateness of the coordinates of the points on the screen entail that the direction of the wave normal at the screen is the same for all solutions.

This is my claim. The following by way of more detailed explanation. In the following way you obtain all of the solutions that general covariance brings in its train in the above special case. Trace the little figure above on completely deformable tracing paper. Then deform the tracing paper arbitrarily in the paper-plane. Then again make a copy on notepaper. You obtain then, e.g., the figure

Einstein to Paul Ehrenfest, 25 January 1916



If you now refer the figure again to orthogonal notepaper-coordinates, then the solution is mathematically a different one from before, naturally also with respect to the $g_{\mu\nu}$. But physically it is exactly the same, because even the notepaper-coordinate system is only something imaginary [etwas eingebildetes]. The same points of the plate always receive light. If you carry out the distortion of the tracing paper only in a finite region and in such a way that the image of the star, the screen, and the plate remains undisturbed without violating continuity, then you obtain the special case to which your question refers.

What is essential is this: As long as the drawing paper, i.e., "space," has no reality, the two figures do not differ at all. It is only a matter of "coincidences," e.g., whether points on the plate are struck by light or not. Thus, the difference between your solutions *A* and *B* becomes a mere difference of representation, with physical agreement.

If the equations of physics were not generally covariant, then you could, to be sure, also make the above argument; but the same laws would not hold in the *second* figure, relative to the notepaper-system, as in the first. To that extent the two would not be equally justified. But this difference drops away with general covariance.

Albert Einstein. "Die Grundlage der allgemeinen Relativitätstheorie." ***Annalen der Physik*** **49 (1916), 769-822.**

That this requirement of general co-variance, which takes away from space and time the last remnant of physical objectivity, is a natural one, will be seen from the following reflexion. All our space-time verifications [Konstatierungen] invariably amount to a determination of space-time coincidences. If, for example, events consisted merely in the motions of material points, then ultimately nothing would be observable but the meetings of two or more of these points. Moreover, the results of our measurings are nothing but verifications of such meetings of the material points of our measuring instruments with other material points, coincidences between the hands of a clock and points on the clock dial, and observed point-events happening at the same place at the same time.

The introduction of a system of reference serves no other purpose than to facilitate the description of the totality of such coincidences. . . . As all our physical experiences can be ultimately reduced to such coincidences, there is no immediate reason for preferring certain systems of co-ordinates to others, that is to say, we arrive at the requirement of general covariance.

Question: From What Source Did Einstein Learn to Require that Our Theories Determine a Univocal [“eindeutige”] Model of the Real?

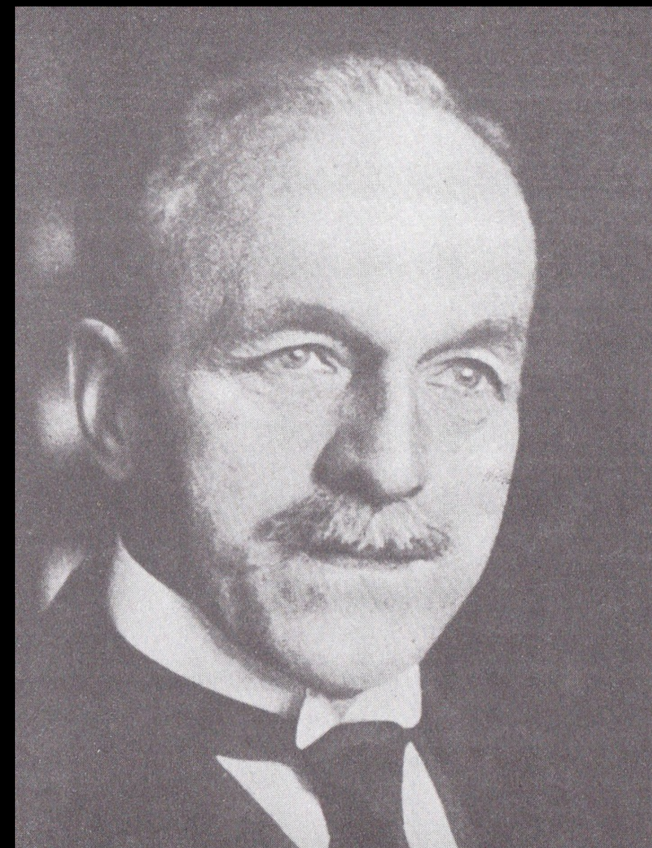
Josef Petzoldt and Eindeutigkeit

Das Gesetz der Eindeutigkeit.

Inhaltsangabe.

1. Die Begriffe Ursache und Wirkung sind nicht haltbar. Die Beantwortung der Frage, was an ihre Stelle treten soll, kann in einer Betrachtung der physikalischen Gleichungen gesucht werden. — 2. Wundt's Auffassung und Classification der physikalischen Gleichungen. — 3. Kritik dieser Auffassung. — 4. Weitere Analyse der Gleichungen der Physik. — 5. Das Gesetz der Erhaltung der Energie als Ausdruck für den Zusammenhang aller Erscheinungen. — 6. Der Sinn des Gleichungsschemas überhaupt. Die simultane Abhängigkeit der Erscheinungen. Mach's Umschreibung des allgemeinen Inhalts der physikalischen Gleichungen. — 7. Frage nach der durchgängigen Bestimmtheit der Natur. Mach's Hinweis auf zwei Umstände, die ihm Unbestimmtheiten bedeuten. — 8. Das Postulat der Eindeutigkeit alles Seins und Geschehens. — 9. Kritik der Mach'schen Ansicht von der theilweisen Unbestimmtheit der Natur. Die Eindeutigkeit in der Succession der Naturerscheinungen. — 10. Die Kriterien der succedanen Abhängigkeit der Erscheinungen. — 11. Der Ersatz für die aufgegebenen Causalitätsvorstellungen. — 12. Kritik der Wundt'schen Auffassung der complicirteren Lebens- und Gehirnvorgänge hinsichtlich ihrer »Causalität«. — 13. Die Bewegungsvorgänge als ausgezeichnete Fälle. — 14. Das Hertz'sche Grundgesetz der Mechanik. Sein Verhältniss zu Henke's Verallgemeinerung des Princips der Methode der kleinsten Quadrate. — 15. Das Trägheitsgesetz. — 16. Ostwald's Ausdehnung des Princips des ausgezeichneten Falles auf das Gebiet der Energetik. Das Gesetz der Eindeutigkeit in seiner Bedeutung für die Begründung des Energiegesetzes. — 17. Das Gesetz der Eindeutigkeit gilt innerhalb des Gebietes des »Psychischen« nicht. — 18. Dennoch müssen auch die psychischen Erscheinungen eindeutig bestimmte sein. Die Sätze der Identität und des Widerspruchs. — 19. Die Begründung des Princips des psychophysischen Parallelismus durch das Princip der Eindeutigkeit. — 20. Wie lässt sich auf psychischem Gebiet mit dem Mangel an Eindeutigkeit das Bestehen von Gesetzen vereinigen? — 21. Zusammenfassung. Der Satz der Eindeutigkeit als Princip und als Gesetz.

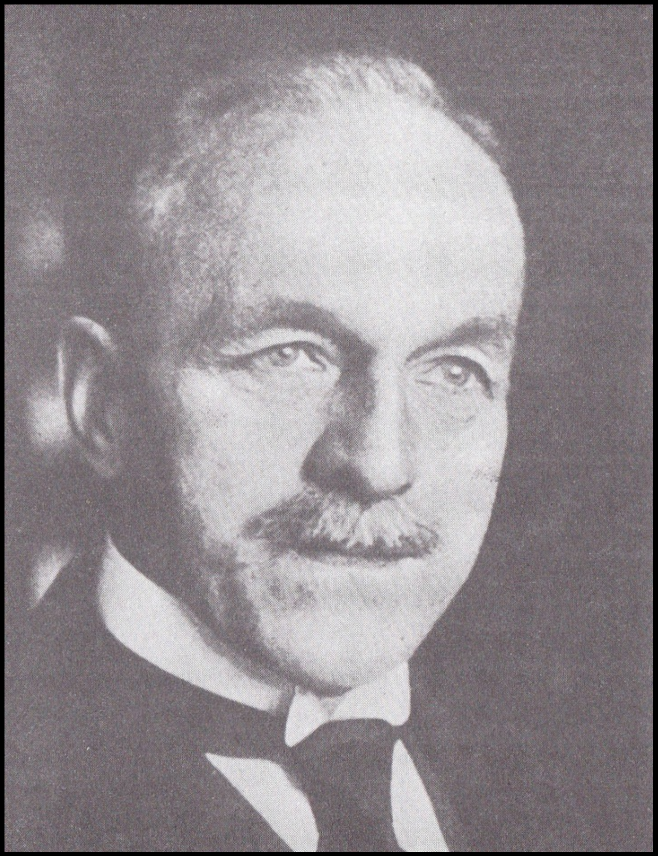
Joseph Petzoldt. “Das Gesetz der Eindeutigkeit.” *Vierteljahrsschrift für wissenschaftliche Philosophie und Soziologie* 19 (1895), 146-203.



Joseph Petzoldt (1862-1929)

Josef Petzoldt and Eindeutigkeit

We must . . . bring to bear on nature a certain general presupposition, without whose confirmation we ourselves could not live, either mentally or bodily. Such a presupposition lies at the base of all scientific research, something of which we may be more or less consciously aware, and we may be of the firm conviction that it will hold up everywhere, since we could not conceive of ourselves, with our particular mental nature, if we once imagine it being given up. Both our individual constitution and that postulate, as we may designate the relevant presupposition, belong inseparably together. The latter consists in nothing other than the assumption of the *thoroughgoing complete determination*, or – as we want to say in order to emphasize the most important side of the matter – in the assumption of the *uniqueness of all processes* [*Eindeutigkeit aller Vorgänge*].



Joseph Petzoldt (1862-1929)

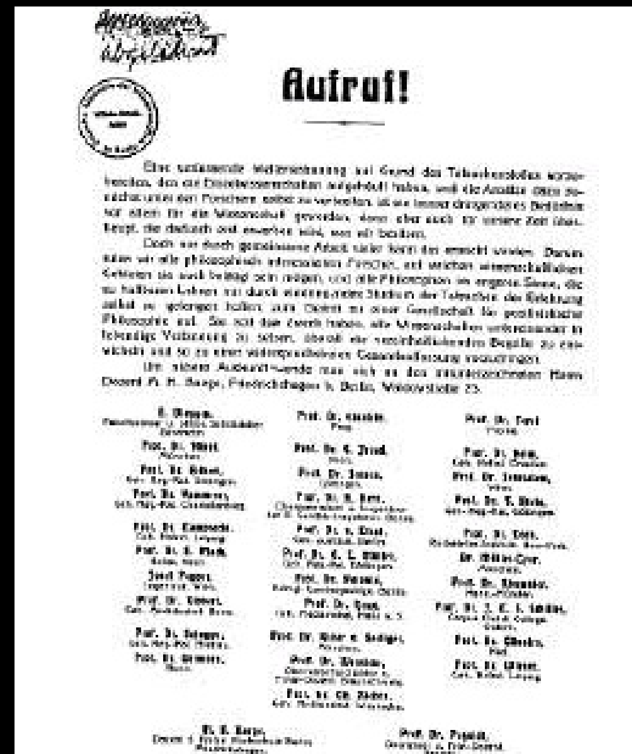
Joseph Petzoldt. "Das Gesetz der Eindeutigkeit." *Vierteljahrsschrift für wissenschaftliche Philosophie und Soziologie* 19 (1895), 146-203.

Petzoldt on Eindeutigkeit and Relativity

The task of physics becomes, thereby, the *eindeutige* general representation of events from different standpoints moving relative to one another with constant velocities, and the *eindeutige* setting-into-relationship of these representations. Every such representation of whatever totality of events must be *eindeutig* mappable onto every other one of these representations of the same[1)] events. The theory of relativity is one such mapping theory. What is essential is that *eindeutige* connection. Physical concepts must be bent to fit for its sake. We have theoretical and technical command only of that which is represented *eindeutig* by means of concepts.

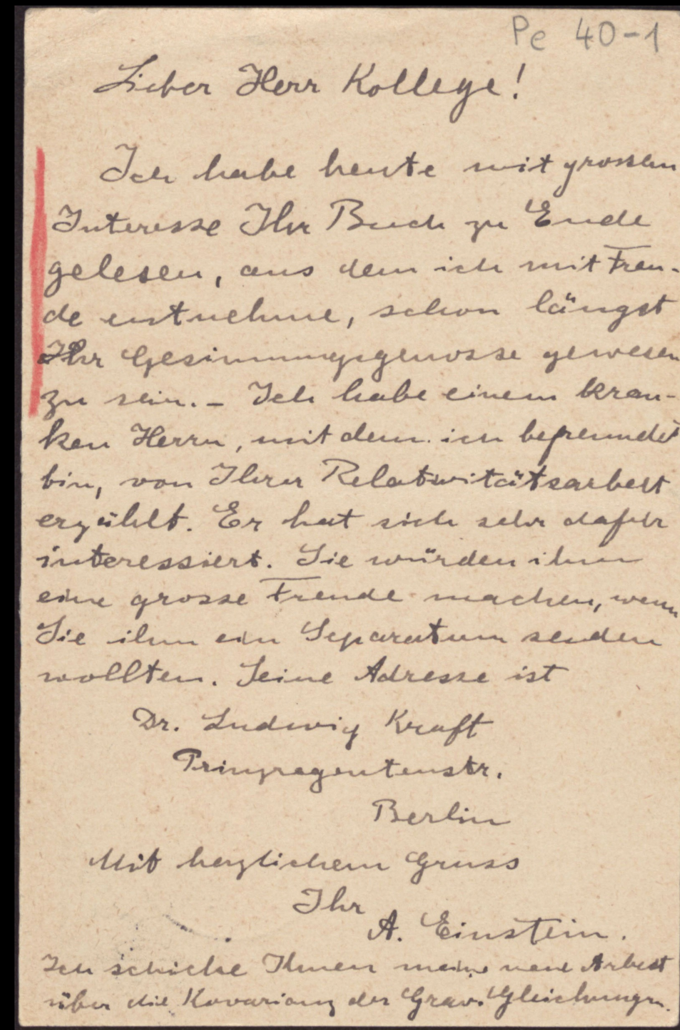
[1)] Better: representations of events in arbitrarily many of those systems of reference that are *eindeutig* mappable onto one another are representations of '*the same*' event. Identity must be *defined*, since it is not given from the outset.

Joseph Petzoldt. "Die Relativitätstheorie im erkenntnistheoretischer Zusammenhange des relativistischen Positivismus." *Deutsche Physikalische Gesellschaft. Verhandlungen* 14 (1912),1055-1064.


Aufruf!

Call for the Establishment of the Gesellschaft für positivistische Philosophie, 1912

Petzoldt on Eindeutigkeit and Relativity



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Lieber Herr Kollege!

Ich habe heute mit grossem Interesse Ihr Buch zu Ende gelesen, aus dem ich mit Freude entnehme, schon längst Ihr Gesinnungsgenosse gewesen zu sein. – Ich habe einem kranken Herrn, mit dem ich befreundet bin, von Ihrer Relativitätsarbeit erzählt. Er hat sich sehr dafür interessiert. Sie würden ihm eine grosse Freude machen, wenn Sie ihm ein Separatum senden wollten. Seine Adresse ist

Dr. Ludwig Kraft
Prinzregentenstr.
Berlin

Mit herzlichem Gruss
Ihr A. Einstein.

Ich schicke Ihnen meine neue Arbeit über die Kovarianz der Grav. Gleichungen.

Joseph Petzoldt. *Das Weltproblem vom Standpunkte des relativistischen Positivismus aus, historisch-kritisch dargestellt*, 2nd ed. Wissenschaft und Hypothese, vol. 14. Leipzig and Berlin: B. G. Teubner, 1912.

Carnap on Monomorphic Concepts and Empirical Content

Proper Concepts are categorical (monomorphic) and defined via explicit definitions in terms of the primitives of one's protocol language, such as a phenomenalist protocol language whose primitive terms refer to Elementarerlebnisse.

Improper Concepts are non-categorical and defined implicitly by the systematic role they play in the axiom system of one's theory.

Only explicitly defined and hence categorical proper concepts at the basic level can guarantee that a theory possesses determinate empirical content.

Rudolf Carnap (1891-1970)

Rudolf Carnap. "Eigentliche und Uneigentliche Begriffe." *Symposion. Philosophische Zeitschrift für Forschung und Ausprache* 1 (1927), 355-374.

Carnap on Monomorphic Concepts and Empirical Content

In the systematic construction of the knowledge of reality, real concepts are constituted step-by-step. As a term in this construction, every real concept possesses an immediate relation to reality. By contrast, improper concepts so-to-say hover in mid-air. They are introduced through an *AS* that does not refer directly to reality. The axioms of this *AS* and the theorems deduced from them do not properly constitute a theory (since, indeed, they deal with nothing determinate), but only a theory-schema, an open form for possible theories. But if, in the system of knowledge, a real concept appears for which it can be shown empirically that it has the formal makeup indicated in the *AS* for the improper concept, then the *AS* has found a realization: In place of the improper concept, which is just a variable, the real concept can be substituted. Thus, the structures of physical space (points, lines, etc.) evince empirically the makeup that the axioms of geometry express for "points" (in the improper sense), etc. . . . Through this contact between the real concept and the axioms (the former satisfy the latter), the connection to the entire theory-schema based on the *AS* is accomplished in one stroke. The blood of empirical reality streams in through this one point of contact and flows into the most highly branched veins of the heretofore empty schema, which is thereby transformed into a filled-out theory.

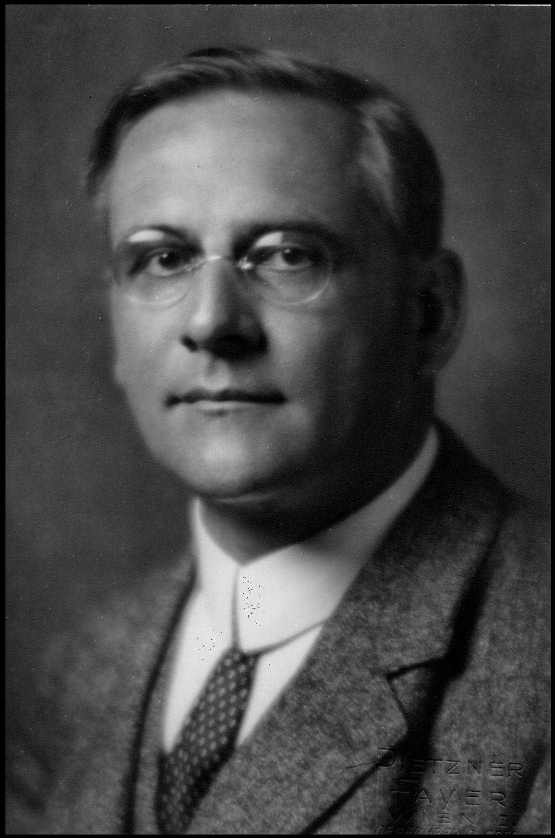
Rudolf Carnap. "Eigentliche und Uneigentliche Begriffe." *Symposion. Philosophische Zeitschrift für Forschung und Ausprache* 1 (1927), 355-374.

Point Coincidences or Pointer Coincidences?

Schlick to Einstein, 4 February 1917

The essay is less a presentation of the general theory of relativity itself and more a thoroughgoing exposition of the proposition that, in physics, space and time have now forfeited all objectivity [alle Gegenständlichkeit eingebüsst haben].

[Moritz Schlick. "Raum und Zeit in der gegenwärtigen Physik. Zur Einführung in das Verständnis der allgemeinen Relativitätstheorie." *Die Naturwissenschaften* 5 (1917), 161-167, 177-186.]



Moritz Schlick (1882-1936)

Moritz Schlick. ***Raum und Zeit in der gegenwärtigen Physik. Zur Einführung in das Verständnis der allgemeinen Relativitätstheorie*. Berlin: Julius Springer, 1917.**

Experiences of coincidences must be taken into consideration here. In order to determine a point in space, one must somehow, directly or indirectly, *point* to it [*hinzeigen*], one must make the point of a compass, or a finger, or a set of cross-hairs, coincide with it [zur Deckung bringen], that is, one sets up a spatiotemporal coincidence of two otherwise separated elements. Now it turns out that these coincidences always appear to agree for all the intuitional spaces of the various senses and for various individuals; for just that reason, an objective "point" is defined by them, i.e., one independent of individual experiences and valid for all. . . . Upon more careful reflection, one easily finds that we arrive at the construction of physical space and time exclusively by this method of coincidences and in no other way. The spacetime manifold is precisely nothing other than the totality of objective elements defined by this method.

This is the result of the psychological-empiriocritical analysis of the space and time concept, and we see that we encounter precisely *the* significance of space and time that Einstein recognized as alone essential for physics and there gave proper expression. For he repudiated the Newtonian conception . . . and instead founded physics on the concept of the coincidence of events.

Einstein to Moritz Schlick, 21 May 1917

The second point to which I want to refer concerns the reality concept. Your view stands opposed to Mach's according to the following schema:

> Mach: Only impressions are real.
> Schlick: Impressions and events (of a phys[ical] nature) are real.

Now it appears to me that the word "real" is taken in different senses, according to whether impressions or events, that is to say, states of affairs in the physical sense, are spoken of.

If two different peoples pursue physics independently of one another, they will create systems that certainly agree as regards the impressions ("elements" in Mach's sense). The mental constructions that the two devise for connecting these "elements" can be vastly different. And the two constructions need not agree as regards the "events"; for these surely belong to the conceptual constructions. Certainly only the "elements," but not the "events," are real in the sense of being "given unavoidably in experience."

But if we designate as "real" that which we arrange in the space-time-schema, as you have done in the theory of knowledge, then without doubt the "events," above all, are real.

Now what we designate as "real" in physics is, no doubt, the "spatio-temporally-arranged," not the "immediately-given." The immediately-given can be illusion, the spatio-temporally arranged can be a sterile concept that does not contribute to illuminating the connections between the immediately-given. *I would like to recommend a clean conceptual distinction here*.

Hans Reichenbach. *Philosophie der Raum-Zeit-Lehre*. Berlin and Leipzig: Walter de Gruyter, 1928.

It is a serious mistake to identify a coincidence, in the sense of a point-event of space-time order, with a coincidence in the sense of a sense experience. The latter is *subjective coincidence*, in which sense perceptions are blended. . . . The former, on the other hand, is *objective* coincidence, in which physical things, such as atoms, billiard balls or light rays collide and which can take place even when no observer is present. The space-time order deals only with objective coincidences, and we go outside the realm of its problems in asking how the system of objective coincidences is related to the corresponding subjective system. The analysis of this question belongs to that part of epistemology that explains the connection between objective reality, on the one hand, and consciousness and perception on the other. Let us say here only that any statement about objective coincidences has the same epistemological status as any other statement concerning a physical fact.

It is therefore not possible to reduce the topology of space and time to subjective grounds springing from the nature of the observer. On the contrary, we must specify the principles according to which an objective coincidence is to be ascertained. This means that we must indicate a method how to decide whether a physical event is to be considered as one, or as two or more separate point events.

Hans Reichenbach. *Philosophie der Raum-Zeit-Lehre*. Berlin and Leipzig: Walter de Gruyter, 1928.

Objective coincidences are therefore physical events like any others; their occurrence can be confirmed only within the context of theoretical investigation. Since all happenings have until now been reducible to objective coincidences, we must consider it the most general empirical fact that the physical world is a system of coincidences. It is this fact on which all spatio-temporal order is based, even in the most complicated gravitational fields. What kind of physical occurrences are coincidences, however, is not uniquely determined by empirical evidence, but depends again on the totality of our theoretical knowledge.

Narrative Two: Neo-Kantianism, Conventionalism, and the “New Empiricism.”

Henri Poincaré. "L'Expérience et la Géométrie." In *La science et l'hypothèse*. Paris: Ernest Flammarion, 1902.

Poincaré's Geometric Conventionalism

A metrical geometry acquires empirical content only through conventional defintions as with the definition of "straight line segment" as "segment of the path of a ray of light."

Conventional definitions are distinguished from contentful, empirical assertions, such as the ascription of a metrical structure to a space.

Example – cosmic triangulation.

The moment of conventionality is confined to those conventional analytic definitions, the assertion of which fixes the univocal empirical content of the remaining, synthetic, empirical propositions.

Henri Poincaré (1854-1912)

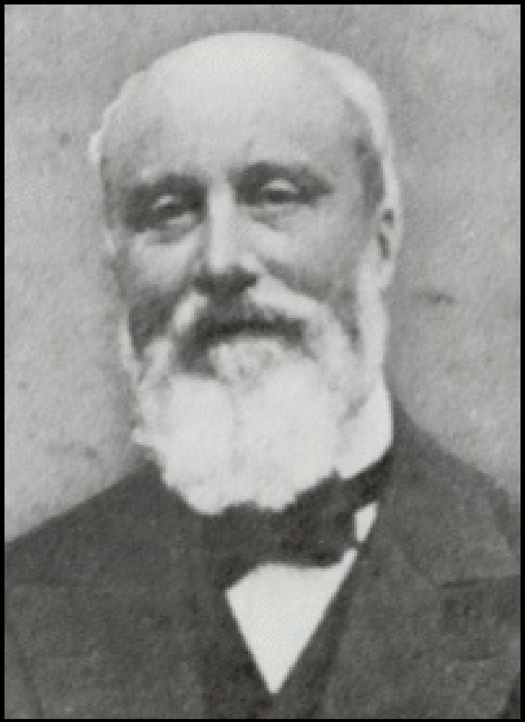
Pierre Duhem. ***La Théorie physique, son objet et sa structure*****.**
Paris: Chevalier & Rivière, 1906.

Ch. 6, "Physical Theory and Experiment"

All theories are tested only as wholes, individual propositions never being tested in isolation.

In consequence, theory choice is underdetermined by evidence, allowing for a conventional choice among alternative, empirically equivalent theories.

Moreover, in consequence of this theory holism, one cannot effect a principled, systematic distinction between analytic defnitions and synthetic, empirical claims.



Pierre Duhem (1861-1916)

Moritz Schlick. "Die philosophische Bedeutung des Relativitätsprinzips." *Zeitschrift für Philosophie und philosophische Kritik* 159 (1915), 129-175.

The totality of our scientific propositions, in word and formula, is in fact nothing else but a system of symbols *correlated* to the facts of reality; and that is equally certain, whether we declare reality to be a transcendent being or merely the totality and interconnection of the immediately "given." The system of symbols is called "true," however, if the correlation is completely univocal. Certain features of this symbol system are left to our arbitrary choice; we can select them in this way or that without damaging the univocal character of the correlation. It is therefore no contradiction, but lies, rather, in the nature of the matter, that under certain circumstances, several theories may be true at the same time, in that they achieve indeed a different, but each for itself completely univocal designation of the facts.

See also:

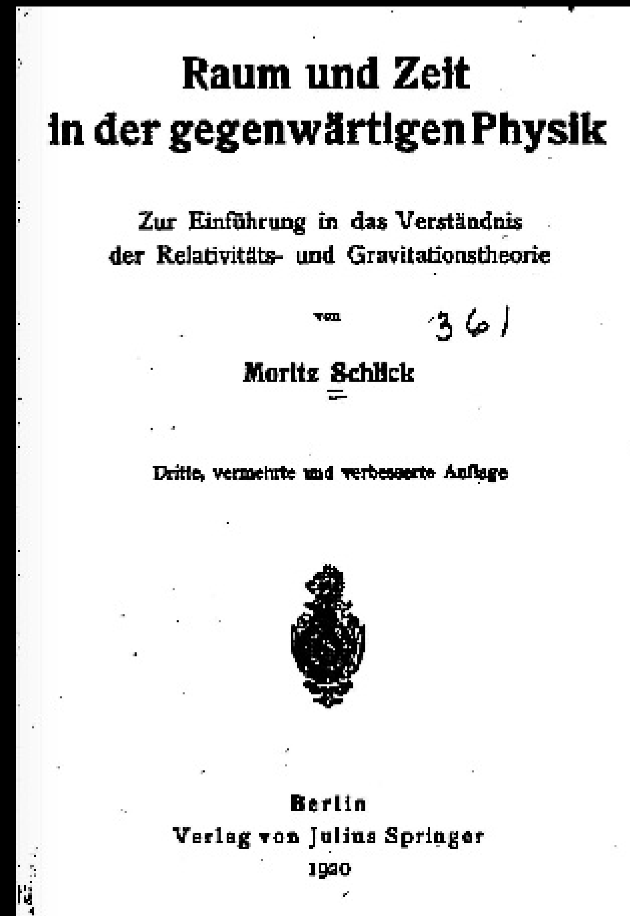
Moritz Schlick. "Das Wesen der Wahrheit nach der modernen Logik." *Vierteljahrsschrift für wissenschaftliche Philosophie und Soziologie* 34 (1910), 386-477.

Moritz Schlick. ***Raum und Zeit in der gegenwärtigen Physik. Zur Einführung in das Verständnis der allgemeinen Relativitätstheorie*****. Berlin: Julius Springer, 1917.**

Every theory consists of a structure of concepts and judgments, and it is *correct* or *true* if the system of judgments is *univocally* correlated with the world of facts. . . . It is, however, possible to indicate the *same* set of facts by means of *different* systems of judgments; consequently there can be different theories for which the criterion of truth holds in the same way, and which then do justice in equal measure to the observed facts and lead to the same predictions. They are different systems of symbols that are correlated to the same objective reality, different modes of expression that reproduce the same set of facts.

Einstein to Schlick, 21 May 1917

Again and again I take a look at your little book and am delighted by the splendidly clear expositions. And the last section, ‘Relations to Philosophy,’ appears to me to be excellent.


Raum und Zeit
in der gegenwärtigen Physik

Zur Einführung in das Verständnis
der Relativitäts- und Gravitationstheorie

von 361

Moritz Schlick

Dritte, vermehrte und verbesserte Auflage

Berlin
Verlag von Julius Springer
1920

The Neo-Kantian Reaction to General Relativity Begins

The Neo-Kantian Reaction to General Relativity Begins

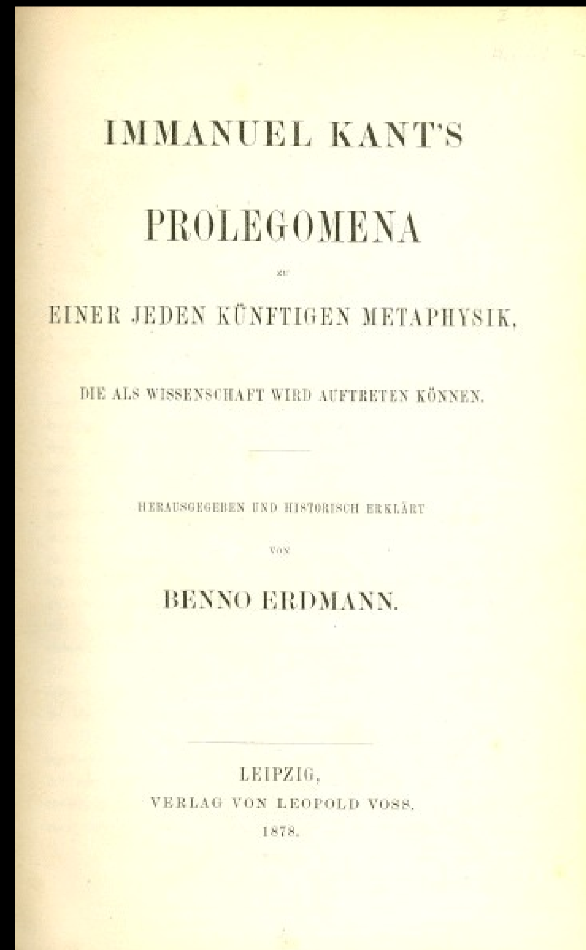
Immediately after WWI, and even more so after the announcement of Eddington's eclipse observations, there was an explosion of books and papers from with the neo-Kant camp reacting to general relativity's assertion of the variable metrical structure of space-time, which challenged the Kantian assertion of the necessary a priori status of Euclidean geometry as the form of outer intiution.

Reactions varied from outright rejection of general relativity to various modifications of Kantian doctrine, as with restricting its validity to "psychological" space, not physical space, or limiting claims about a priori structure to structure weaker than metrical structure, such as, just topological structure.

This created a kind of crisis among empiricist eager to defend the empirical integrity of general relativity.

Einstein to Max Born, July 1918

I am reading Kant’s *Prolegomena* here, among other things, and am beginning to comprehend the enormous suggestive power that emanated from the fellow and still does. Once you concede to him merely the existence of synthetic a priori judgments, you are trapped. I have to water down the “a priori” to “conventional,” so as not to have to contradict him, but even then the details do not fit. Anyway it is very nice to read, even if it is not as good as his predecessor Hume’s work. Hume also had a far sounder instinct.



IMMANUEL KANT'S

PROLEGOMENA

ZU

EINER JEDEN KÜNFTIGEN METAPHYSIK,

DIE ALS WISSENSCHAFT WIRD AUFTRETEN KÖNNEN.

HERAUSGEGEBEN UND HISTORISCH ERKLÄRT

VON

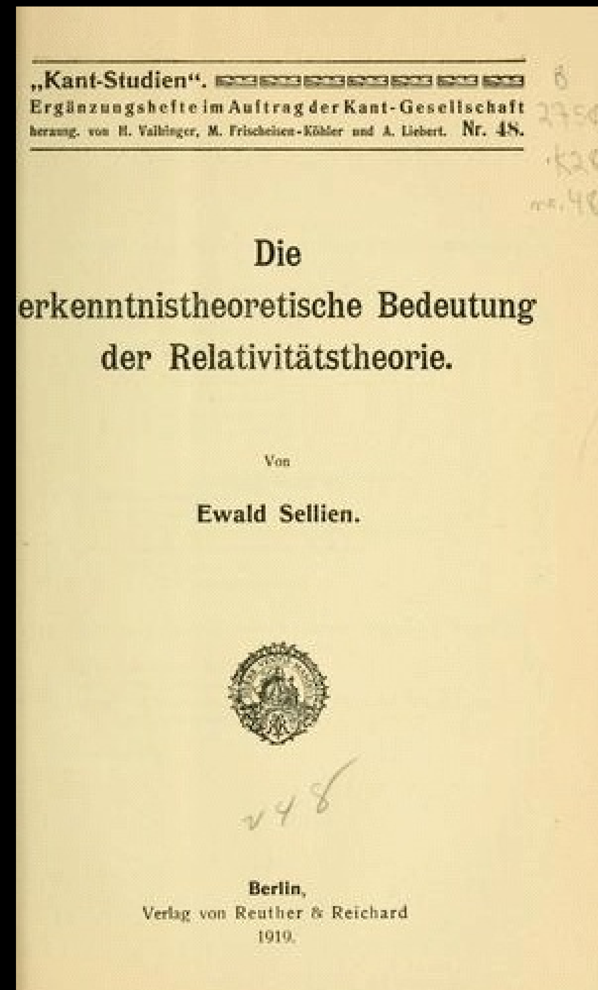
BENNO ERDMANN.

LEIPZIG,
VERLAG VON LEOPOLD VOSS.
1878.

Einstein to Ilse Schneider, 15 September 1919

I have received the mentioned dissertation by S. [Ewald Sellien] (Epistemology and Relativity Theory). . . . Kant's celebrated view on time reminds me of Andersen's tale about the emperor's new clothes, except that instead of the emperor's clothes, it concerns the form of intuition.

[Ewald Sellien. *Die erkenntnistheoretische Bedeutung der Relativitätstheorie*. "Kant-Studien" Ergänzungshefte, no. 48. Berlin: Reuther & Reichard, 1919.]



„Kant-Studien".
Ergänzungshefte im Auftrag der Kant-Gesellschaft
herausg. von H. Vaihinger, M. Frischeisen-Köhler und A. Liebert. Nr. 48.

Die
erkenntnistheoretische Bedeutung
der Relativitätstheorie.

Von

Ewald Sellien.

v48

Berlin,
Verlag von Reuther & Reichard
1919.

Ernst Cassirer

Ernst Cassirer. *Zur Einsteinschen Relativitätstheorie. Erkenntnistheoretische Betrachtungen*. Berlin: Bruno Cassirer, 1921.

Ernst Cassirer (1874-1945)

Einstein to Ernst Cassirer, 5 June 1920

I can understand your idealistic way of thinking about space and time, and I even believe that one can thus achieve a consistent point of view. To me, as a non-philosopher, philosophical contrarieties appear more contrarieties of emphasis than contrarieties of a principled kind. What Mach calls *connections*, are for you ideal names, which experience first makes possible. But you emphasize this side of knowledge, whereas Mach wants to make them appear as insignificant as possible. I acknowledge that one must approach the experiences with some sort of conceptual functions, in order for science to be possible; but I do not believe that we are placed under any constraint in the choice of these functions *by virtue of the nature of our intellect.* Conceptual systems appear empty to me, if the manner in which they are to be referred to experience is not established. This appears most essential to me, even if, to our advantage, we often isolate in thought the purely conceptual relations, in order to permit the *logically* secure connections to emerge more purely.

The Crucial Moment

Hans Reichenbach. *Relativitätstheorie und Erkenntnis Apriori*. Berlin: Julius Springer, 1920.

A central thesis of Reichenbach's –

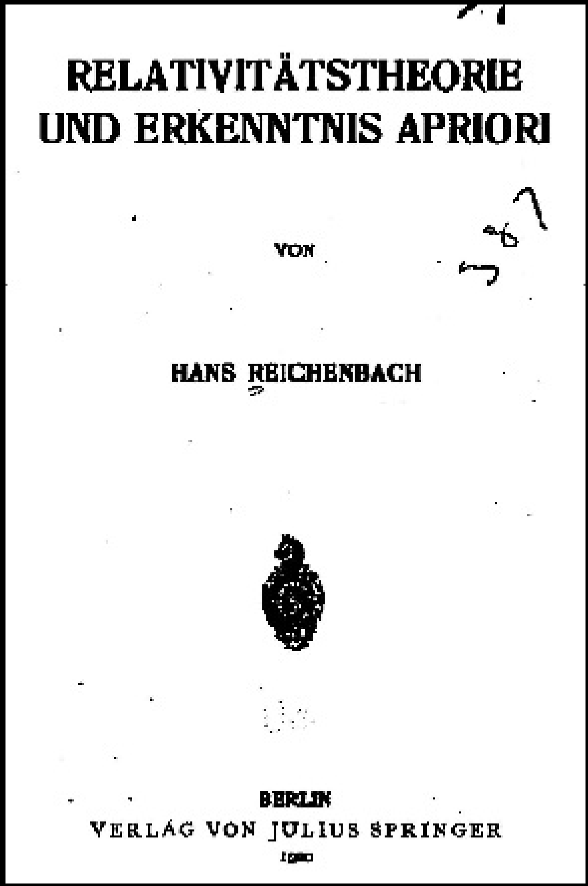
Distinguish the constitutive role of the a priori from its apodicticity; retain the former, deny the latter.

Constitutive principles of coordination make possible the ascription of empirical content to physical theories.

Hans Reichenbach (1891-1953)

Schlick to Einstein, 9 October 1920

In the last few days I have read with the greatest pleasure the booklet by Reichenbach on relativity theory and a priori knowledge. The work really appears to me to be a quite splendid contribution to the axiomatics of the theory and of physical knowledge in general. . . . Of course, in a few points I still cannot entirely support Reichenbach. . . . Reichenbach seems to me not to be fair with regard to the theory of conventions of Poincaré; what he calls a priori principles of coordination, and rightly distinguishes from the empirical principles of connection, seem to me to be wholly identical with Poincaré's "conventions" and to have no significance beyond that. R.'s reliance upon Kant seems to me to be, carefully considered, only purely terminological.


RELATIVITÄTSTHEORIE
UND ERKENNTNIS APRIORI

VON

HANS REICHENBACH

BERLIN
VERLAG VON JULIUS SPRINGER

Schlick to Reichenbach, 26 November 1920

For me the presupposition of object-constituting principles is so self-evident that I have not pointed it out emphatically enough, above all in the Allg. Erkenntnisl. . . . It is quite clear to me that a perception can become an “observation” or even a “measurement” only through certain principles being presupposed by means of which the observed or measured object is then constructed. In this sense the principles are to be called a priori. . . . But there are indeed, moreover, two possibilities, that those principles are hypotheses or that they are conventions. In my opinion, precisely this turns out to be the case, and it is the central point of my letter, that I cannot discern wherein your a priori propositions are actually distinguished from conventions.

Reichenbach to Schlick, 29 November 1920

You ask me why I do not call my a priori principles *conventions*. I believe that we will easily come to agreement about this question. Even though several systems of principles are possible, nevertheless, only one *group* of principle-systems is always possible; and precisely in this restriction there lies some knowledge. Every possible system signifies in its possibility a *property* of reality. I miss in Poincaré an emphasis on the fact that the arbitrariness of the principles is restricted, in the way one *combines* principles. For that reason I cannot adopt the name "convention."

Schlick to Reichenbach, 11 December 1920

1) on the question of the "conventions." If Poincaré did not explicitly emphasize that conventions are not independent of one another, but are always possible only as groups, still one would naturally do him quite an injustice, if one believed, that he was not aware of this circumstance.

Moritz Schlick. "Kritizistische oder empiristische Deutung der neuen Physik." ***Kant-Studien*** **26 (1921), 96-111.**

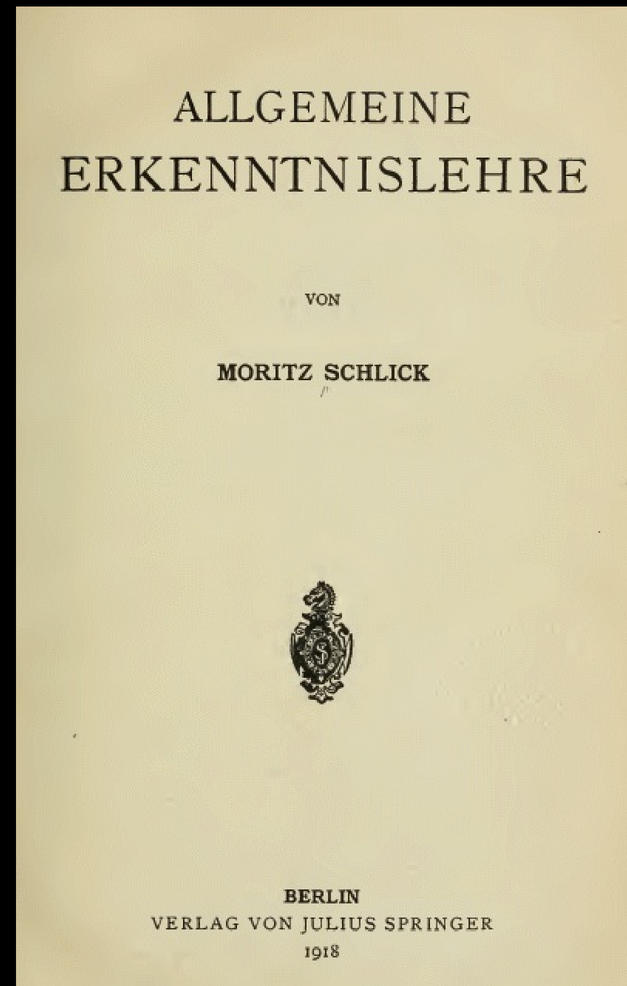
The forming of concepts of physical objects unquestionably presupposes certain principles of ordering and interpretation. Now I see the essence of the critical viewpoint in the claim that these constitutive principles are *synthetic a priori judgements*, in which the concept of the *a priori* has the property of apodeicticity (of universal, necessary and inevitable validity) inseparably attached to it. . . . The most important consequence of the view just elaborated is that a thinker who simply perceives the necessity of constitutive principles for scientific experience should not yet be called a critical philosopher on that account. An empiricist, for example, can very well acknowledge the presence of such principles; he will deny only that they are synthetic and *a priori* in the sense defined above.

He [Cassirer] quite rightly condemns the attempt sometimes made by Mach, to treat even analytico-mathematical laws like things "whose properties one can read off by immediate perception," but that does not prove the truth of logical idealism, it merely refutes the sensualist theory. Between the two we still have the empiricist viewpoint, according to which these constitutive principles are either *hypotheses* or *conventions*; in the first case they are not *a priori* (since they lack apodeicticity), and in the second they are not synthetic.

Moritz Schlick. ***Allgemeine Erkenntnislehre*****, 2nd ed. Berlin: Julius Springer, 1925.**

Every judgment we make is either definitional or cognitive. This distinction, as we noted above (§ 8), has only a relative significance in the conceptual or “ideal” sciences. It emerges all the more sharply, however, in the empirical or “real” sciences. In these sciences it has a fundamental importance; and a prime task of epistemology is to make use of this distinction in order to clarify the kinds of validity possessed by various judgments.

The system of definitions and cognitive judgments, which constitutes any real science, is brought into congruence at individual points with the system of reality, and is so constructed that congruence then follows automatically at all remaining points. . . . If the whole edifice is correctly built, then a set of real facts corresponds not only to each of the starting points—the fundamental judgments—but also to each member of the system generated deductively. Every individual judgement in the entire structure is uniquely coordinated to a set of real facts.



ALLGEMEINE
ERKENNTNISLEHRE

VON

MORITZ SCHLICK

BERLIN
VERLAG VON JULIUS SPRINGER
1918

Hans Reichenbach. *Axiomatik der relativistischen Raum-Zeit-Lehre*. Die Wissenschaft, vol. 72. Braunschweig: Friedrich Vieweg und Sohn, 1924.

It is characteristic of the axiomatization of physics compared to that of mathematics that there exists such a distinction between axioms and definitions; an essential task of the axiomatization consists in tracing this distinction within the theoretical system.

However, even definitions in physics are different from definitions in mathematics. The mathematical definition is a *conceptual definition*, that is, it clarifies the meaning of a concept by means of other concepts. The physical definition takes the meaning of the concept for granted and coordinates to it a physical thing; it is a *coordinative definition*. Physical definitions, therefore, consist in the coordination of a mathematical definition to a "piece of reality"; one might call them *real definitions*.

Hans Reichenbach. *Philosophie der Raum-Zeit-Lehre*. Berlin and Leipzig: Walter de Gruyter, 1928.

Defining usually means reducing a concept to other concepts. In physics, as in all other fields of inquiry, wide use is made of this procedure. There is a second kind of definition, however, which is also employed and which derives from the fact that physics, in contradistinction to mathematics, deals with real objects. Physical knowledge is characterized by the fact that concepts are not only defined by other concepts, but are also coordinated to real objects. This coordination cannot be replaced by an explanation of meanings, it simply states that *this concept* is coordinated to *this particular thing*. In general this coordination is not arbitrary. Since the concepts are interconnected by testable relations, the coordination may be verified as true or false, if the requirement of uniqueness is added, i.e., the rule that the same concept must always denote the same object. The method of physics consists in establishing the uniqueness of this coordination, as Schlick has clearly shown. But certain preliminary coordinations must be determined before the method of coordination can be carried through any further; these first coordinations are therefore definitions which we shall call *coordinative definitions*. They are *arbitrary,* like all definitions; on their choice depends the conceptual system which develops with the progress of science.

The Two Narrative Lines Intersect

Carnap on Monomorphic Concepts and Empirical Content

Proper Concepts are categorical (monomorphic), hence univocal or *eindeutig*, and defined via explicit definitions in terms of the primitives of one's protocol language, such as a phenomenalist protocol language whose primitive terms refer to *Elementarerlebnisse*.

Improper Concepts are non-categorical and defined implicitly by the systematic role they play in the axiom system of one's theory.

Only explicitly defined and hence categorical proper concepts at the basic level can guarantee that a theory possesses determinate empirical content.

Rudolf Carnap (1891-1970)

Rudolf Carnap. "Eigentliche und Uneigentliche Begriffe." *Symposion. Philosophische Zeitschrift für Forschung und Ausprache* 1 (1927), 355-374.

Moritz Schlick. "Sind die Naturgesetze Konventionen?" ***Actes du Congrès International de Philosophie Scientifique, Paris 1935*****. Vol. 4,** ***Induction et Probabilité*****. Actualités Scientifique et Industrielles, no. 391. Paris: Hermann, 1936, 8-17.**

What is arbitrary are, first, the rules which determine the mutual relations of the symbols used, the mathematical axioms, and the explicit definitions of the derived concepts of natural science and, secondly, the ostensive definitions by means of which, in the last analysis, the meanings of the fundamental concepts of natural science are determined. These rules in their totality form the grammar of the scientific language, i.e., the complete inventory of rules according to which the symbols (letters, words, sentences, etc.) are to be used in the description of facts. All these "grammatical" rules, and these alone, together determine the meaning of the propositions of science. . . . *They* are the only conventions, not the natural laws. It is those rules which turn mere sentences into genuine propositions, for they determine their significance.

Once the rules are fixed, i.e., once agreement is reached regarding the grammar of the scientific language, then there is no longer any choice about how to formulate any facts of nature. After this there is only one possibility, only one way of formulating the sentence which will fulfill the purpose. A natural law can then be represented in only one quite definite form and not in any other. . . .

Thus we see that all genuine propositions, as for instance natural laws, are something objective, something invariant with respect to the manner of representation, and not dependent in any way upon convention. What is conventional and, hence, arbitrary, is only the form of expression, the symbols, the sentences, thus only something external or superficial which is immaterial to the empirical scientist.

Einstein Had Been Pondering the Same Questions

Albert Einstein. ***Geometrie und Erfahrung. Erweiterte Fassung des Festvortrages gehalten an der Preussischen Akademie der Wissenschaften zu Berlin am 27. Januar 1921*****. Berlin: Julius Springer, 1921.**

Why is the equivalence of the practically-rigid body and the body of geometry–which suggests itself so readily–rejected by Poincaré and other investigators? Simply because under closer inspection the real solid bodies in nature are not rigid, because their geometrical behavior, that is, their possibilities of relative disposition, depend upon temperature, external forces, etc. Thus, the original, immediate relation between geometry and physical reality appears destroyed, and we feel impelled toward the following more general view, which characterizes Poincaré's standpoint. Geometry (G) predicates nothing about the behavior of real things, but only geometry together with the totality (P) of physical laws can do so. Using symbols, we may say that only the sum of (G) + (P) is subject to experimental verification. Thus (G) may be chosen arbitrarily, and also parts of (P); all these laws are conventions. All that is necessary to avoid contradictions is to choose the remainder of (P) so that (G) and the whole of (P) are together in accord with experience. Envisaged in this way, axiomatic geometry and the part of natural law which has been given a conventional status appear as epistemologically equivalent.

Albert Einstein. *Geometrie und Erfahrung. Erweiterte Fassung des Festvortrages gehalten an der Preussischen Akademie der Wissenschaften zu Berlin am 27. Januar 1921*. Berlin: Julius Springer, 1921.

Sub specie aeterni Poincaré, in my opinion, is right. The idea of the measuring rod and the idea of the clock coordinated with it in the theory of relativity do not find their exact correspondence in the real world. It is also clear that the solid body and the clock do not in the conceptual edifice of physics play the part of irreducible elements, but that of composite structures, which must not play any independent part in theoretical physics. But it is my conviction that in the present stage of development of theoretical physics these concepts must still be employed as independent concepts; for we are still far from possessing such certain knowledge of the theoretical principles of atomic structure as to be able to construct solid bodies and clocks theoretically from elementary concepts.

. . .

According to the view advocated here, the question whether the continuum has Euclidean, Riemannian, or any other structure is a question of physics proper which must be answered by experience, and not a question of a convention to be chosen on the grounds of mere expediency.

Einstein to Eberhard Zschimmer, 27 September 1922

That which you work out in your essay seems correct to me, at least from the physical side, which is all that I can judge with certainty. In my opinion, though, the important question for the opposition of relativity theory and Kantian philosophy does not emerge sharply enough: are the spatio-temporal, etc. forms, which also ground "a priori" the relativity theory, only convenient tools of descriptions—to be appraised as conventions—or are they givens, necessitated simply by the character of human thought, and inalterable in detail? I, myself, occupy the former standpoint, represented also, e.g., by Helmholtz and Poincaré, whereas it appears to me that Kant's standpoint was more the latter.

[Eberhard Zschimmer, "Die anschauliche Welt und die Invarianz der Naturgesetze nach A. Einstein." *Beiträge zur Philosophie des deutschen Idealismus* 3 (1923), 22-37.]

Albert Einstein. Review of Joseph Winternitz. *Relativitätstheorie und Erkenntnislehre. Eine Untersuchung über die erkenntnistheoretischen Grundlagen der Einsteinschen Theorie und die Bedeutung ihrer Ergebnisse für die allgemeinen Probleme des Naturerkennens*. Wissenschaft und Hypothese, vol. 23. Leipzig and Berlin: B. G. Teubner, 1923. *Deutsche Literaturzeitung* 45 (1924), 20-22.

Thus Winternitz asserts with Kant that science is a mental construction on the basis of a priori principles. That the edifice of our science rests and must rest on principles which are not themselves derived from experience, will be acknowledged without doubt. For me, doubt only arises if one asks about the dignity of those principles, that is, about their irreplaceability. Are those principles at least in part so constituted that their modification would be incompatible with science, or are they collectively mere conventions, like the ordering principle of the words in a lexicon? W. inclines toward the former view, I to the latter.

Albert Einstein. Review of: Alfred Elsbach. *Kant und Einstein. Untersuchungen über das Verhältnis der modernen Erkenntnistheorie zur Relativitätstheorie.* Berlin and Leipzig: Walter de Gruyter, 1924. *Deutsche Literaturzeitung* 45 (1924), 1688-1689.

This does not, at first, preclude one's holding at least to the Kantian *problematic,* as, e.g., Cassirer has done. I am even of the opinion that this standpoint can be rigorously refuted by no development of natural science. For one will always be able to say that critical philosophers have until now erred in the establishment of the a priori elements, and one will always be able to establish a system of a priori elements that does not contradict a given physical system. Let me briefly indicate why I do not find this standpoint natural. A physical theory consists of the parts (elements) A, B, C, D, that together constitute a logical whole which correctly connects the pertinent experiments (sense experiences). Then it tends to be the case that the aggregate of fewer than all four elements, e.g., A, B, D, *without* C, no longer says anything about these experiences, and just as well A, B, C without D. One is then free to regard the aggregate of three of these elements, e.g., A, B, C as a priori, and only D as empirically conditioned. But what remains unsatisfactory in this is always the *arbitrariness in the choice* of those elements that one designates as a priori, entirely apart from the fact that the theory could one day be replaced by another that replaces certain of these elements (or all four) by others.

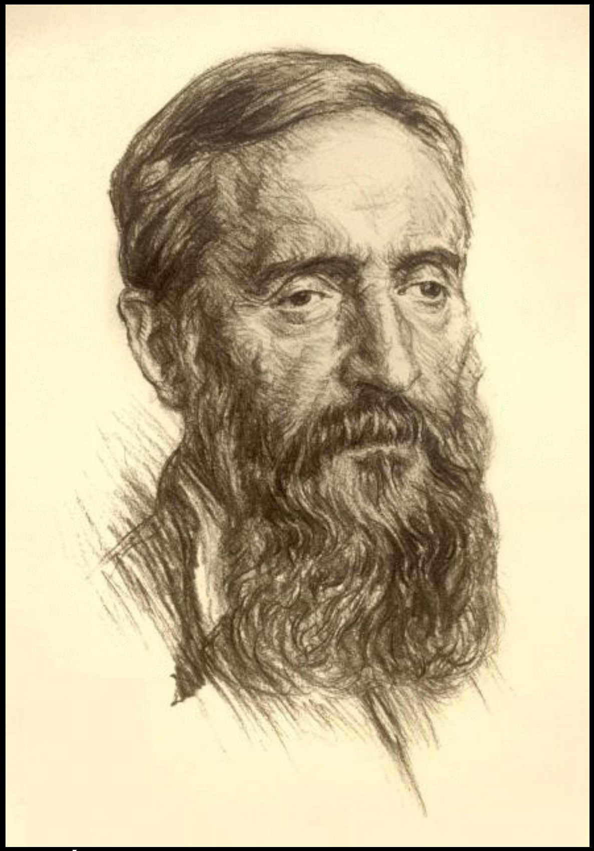
Albert Einstein. Review of: Alfred Elsbach. *Kant und Einstein. Untersuchungen über das Verhältnis der modernen Erkenntnistheorie zur Relativitätstheorie*. Berlin and Leipzig: Walter de Gruyter, 1924. *Deutsche Literaturzeitung* 45 (1924), 1688-1689.

The position that one takes with respect to these theses [Natorp as interpreted by Elsbach] depends on whether one grants reality to the practically-rigid body. If yes, then the concept of the interval corresponds to something experiential. Geometry then contains assertions about possible experiments; it is a physical science that is directly underpinned by experimental testing (standpoint A). If the practically-rigid measuring body is accorded no reality, then geometry alone contains no assertions about experiences (experiments), but instead only geometry with physical sciences taken together (standpoint B). Until now physics has always availed itself of the simpler standpoint A and, for the most part, is indebted to it for its fruitfulness; physics employs the latter in all of its measurements. . . . But if one adopts standpoint B, which seems excessively cautious at the present stage of the development of physics, then geometry alone is not experimentally testable. There are then no geometrical measurements whatsoever. . . . Only a complete scientific conceptual system comes to be univocally coordinated with sensory experience. . . .

Viewed from standpoint B, the choice of geometrical concepts and relations is, indeed, determined only on the grounds of simplicity and instrumental utility. . . . Concerning the metrical determination of space, nothing can then be made out empirically, but not "because is not real," but because, on this choice of a standpoint, geometry is not a *complete* physical conceptual system, but only a part of one such.

Albert Einstein. Review of Émile Meyerson. *La Déduction Relativiste*. Paris: Payot, 1925. *Revue philosophique de la France et de l'étranger* 105 (1928), 161-166.

There is no feature, no characteristic, of the system we are seeking, about which we can know a priori that it must necessarily belong to this system due to the nature of our thought. This also holds for the forms of logic and causality. We can only ask how the system of science (in its states of development thus far) is composed, but not how it *must* be composed. The logical foundations of the system as well as its structure are thus (from a logical point of view) conventional; their only justification lies in the performance of the system vis-à-vis the facts, in its unified character, and in the small number of its premises.



Émile Meyerson (1859-1933)

The Denoument: Einstein the Contrarian

Einstein to Moritz Schlick, 28 November 1930

Generally speaking, your presentation does not correspond to my way of viewing things, inasmuch as I find your whole conception, so to speak, too positivistic. Indeed, physics *supplies* relations between sense experiences, but only indirectly. For me *its essence* is by no means exhaustively characterized by this assertion. I put it to you bluntly: Physics is an attempt to construct conceptually a model of the *real world* as well as of its law-governed structure. To be sure, it must represent exactly the empirical relations between those sense experiences accessible to us; but *only* thus is it chained to the latter. . . . You will be surprised by Einstein the "metaphysician." But in this sense every four- and two-legged animal is, de facto, a metaphysician.

Hans Reichenbach. "The Philosophical Significance of the Theory of Relativity." In Paul Arthur Schilpp, ed. *Albert Einstein: Philosopher-Scientist*. The Library of Living Philosophers, vol. 7. Evanston, IL: The Library of Living Philosophers, 1949, 289-311.

Another confusion must be ascribed to the theory of conventionalism, which goes back to Poincaré. According to this theory, geometry is a matter of convention, and no empirical meaning can be assigned to a statement about the geometry of physical space. Now it is true that physical space can be described by both a Euclidean and a non-Euclidean geometry; but it is an erroneous interpretation of this relativity of geometry to call a statement about the geometrical structure of physical space meaningless. The choice of a geometry is arbitrary only so long as no definition of congruence is specified. Once this definition is set up, it becomes an empirical question *which* geometry holds for a physical space. . . . The combination of a statement about a geometry with a statement of the co-ordinative definition of congruence employed is subject to empirical test and thus expresses a property of the physical world. The conventionalist overlooks the fact that only the incomplete statement of a geometry, in which a reference to the definition of congruence is omitted, is arbitrary; if the statement is made complete by the addition of a reference to the definition of congruence, it becomes empirically verifiable and thus has physical content.

Albert Einstein. “Remarks Concerning the Essays Brought together in this Co-operative Volume.” In Paul Arthur Schilpp, ed. *Albert Einstein: Philosopher-Scientist*. The Library of Living Philosophers, vol. 7. Evanston, IL: The Library of Living Philosophers, 1949, 665-688.

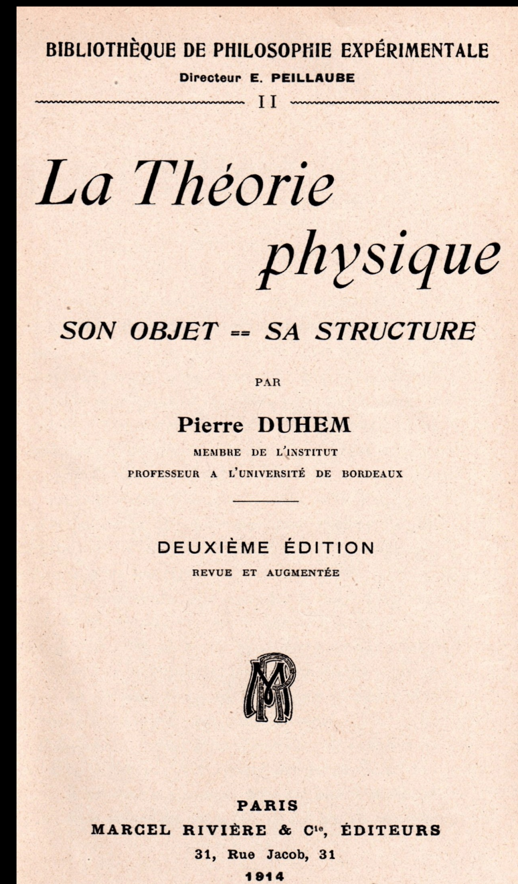
Non-Positivist: If, under the stated circumstances, you hold distance to be a legitimate concept, how then is it with your basic principle (meaning = verifiability)? Must you not come to the point where you deny the meaning of geometrical statements and concede meaning only to the completely developed theory of relativity (which still does not exist at all as a finished product)? Must you not grant that no “meaning” whatsoever, in your sense, belongs to the individual concepts and statements of a physical theory, such meaning belonging instead to the whole system insofar as it makes “intelligible” what is given in experience? Why do the individual concepts that occur in a theory require any separate justification after all, if they are indispensible only within the framework of the logical structure of the theory, and if it is the theory as a whole that stands the test?

This Is Not a Merely Academic Difference. It Makes a Difference in How One Does Physics.

Albert Einstein. "Electricity and Magnetism." Lecture Notes. University of Zurich. Winter Semester 1910-1911.

We have seen how experience led to the introduction of the concept of electrical charge. It was defined with the help of forces that electrified bodies exert on each other. But now we extend the application of the concept to cases in which the definition finds no direct application as soon as we conceive electrical forces as forces that are exerted on material particles but *on electricity*. We establish a conceptual system whose individual parts do not correspond immediately to experiential facts. Only a certain totality of theoretical materials corresponds again to a certain totality of experimental facts.

We find that such an el[ectrical] continuum is always applicable only for representing relations inside of ponderable bodies. Here again we define the vector o[f] el[ectrical] field strength as the vector of the mech[anical] force that is exerted on a unit of pos[itive] electr[ical] charge inside a ponderable body. But the force thus defined is no longer immediately accessible to exp[eriment]. It is a part of a theoretical construction that is true or false, i.e., corresponding or not corresponding to experience, only *as a whole*.



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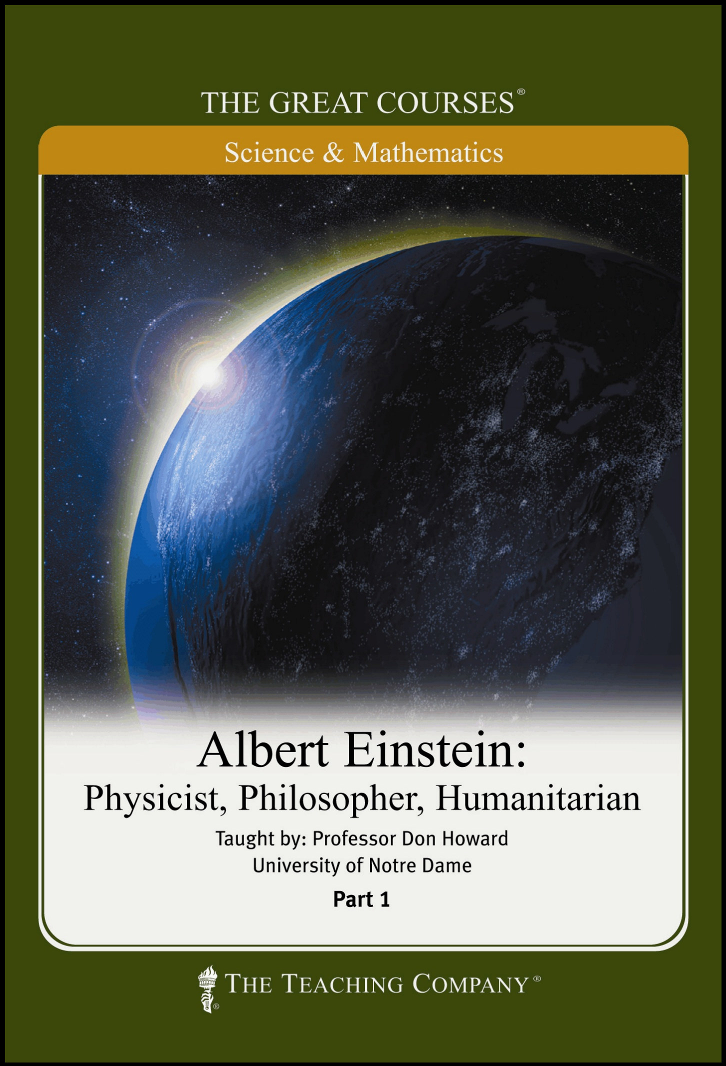

Albert Einstein: Physicist, Philosopher, Humanitarian

Don Howard

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