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BOOK REVIEW

# David Hilbert: Philosophy, epistemology, and the foundations of physics

## Tilman Sauer and Ulrich Majer (eds): David Hilbert's lectures on the foundations of physics 1915–1927: Relativity, quantum theory, and epistemology. Berlin, Heidelberg: Springer, 2009, xii+795pp, €106.95 HB

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This is one volume of an ambitious project to publish David Hilbert's lectures on the foundations of mathematics and physics, 1891–1933. At almost 800 pages, this 1915–1927 collection of Hilbert's work in foundations of physics is in itself a large undertaking. The upshot is a wonderful resource making possible new scholarship on Hilbert as a highly interesting philosopher of physics and epistemologist.

In recent years, Hilbert's deep and long-standing interest in the foundations of physics has begun to receive serious attention from historians and philosophers of physics, through the work of the two editors of this volume, Tilman Sauer and Ulrich Majer, among others, and with the publication of Leo Corry's *David Hilbert and the Axiomatization of Physics (1898–1918)*. The main obstacle facing such scholars has been that Hilbert did not publish much of his work in this area. However, he lectured consistently on topics in physics from the early 1900s onwards (a complete list of Hilbert's lecture courses 1886–1934 is given at the end of the book, pp. 709–726), and this volume makes available lecture materials central to understanding Hilbert's work on foundations of physics. Specifically, Sauer and Majer set out to document three themes of Hilbert's work in the period 1915–1927: (1) the formulation of a generally covariant theory unifying gravitation and electromagnetism; (2) the mathematical formulation of quantum theory and its physical interpretation; and (3) epistemological issues arising from generally covariant physics and from quantum theory.

Not only are the materials brought together and made available for the first time, Sauer and Majer also provide substantial commentary. In their introduction to the volume (24 pages), Sauer and Majer make a strong case for Hilbert as an interesting philosopher of science and epistemologist in his own right, arguing for his deep understanding of, and interest in, the conceptual foundations of physics. They

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provide an overview of Hilbert's work on foundations of physics in this period and context for the materials in the volume. The introduction is itself well worth reading. In addition, each chapter has its own brief introduction, outlining the materials contained and offering commentary on the significance of the materials. The main introduction and chapter introductions are all in English, with quotations in German, and the Hilbert materials are in the original German, with editorial footnotes in English. The work that has gone into framing the book and organizing the materials is itself a significant contribution to Hilbert scholarship.

Hilbert's interest in the formulation of a generally covariant theory unifying gravitation and electromagnetism is familiar from his first and second communications on "Foundations of Physics," published in 1915 and 1917, in which epistemological issues are also addressed. The main materials relevant to this theme are found in chapters 1–3. Hilbert's work on generally covariant physics followed Einstein's visit to Göttingen in the summer of 1915, and Hilbert was closely involved with Einstein as the latter developed his General Theory of Relativity and the Einstein Field Equations. Hilbert's two communications are reproduced in chapter 1 of this volume, along with notes for a two-semester lecture course under the same title, from Summer 1916 and Winter 1916/17 (chapter 2), and the unpublished proofs of the 1915 first communication (chapter 3). These unpublished materials are needed in order to understand Hilbert's published work on its own terms, both as a unification project and with respect to the epistemological issues that concerned Hilbert. Chapter 3 also contains related lecture notes from December 1915 and December 1916, along with notes for a series of lectures on space and time given to German soldiers in Bucharest in 1918 (an interesting story in itself).

The title of chapter 4 is "Epistemological Questions of Physics (1921–1923)" and includes two sets of lecture notes on epistemological issues associated with physics, "Nature and Mathematical Knowledge" and "Principal Questions of Modern Physics." The first set of notes is for a lecture Hilbert gave when he received an honorary doctorate from the University of Copenhagen in March 1921, and the second set is associated with three lectures given by Hilbert at the University of Hamburg in July 1923. The lecture notes include developments of themes that are present in the materials of chapters 1–3. For example, Hilbert discusses in some detail his understanding of the epistemological significance of general covariance as a principle of objectivity and the consequences of general covariance for the problem of causality. With respect to the latter, the epistemological problem for Hilbert is that the world as we experience it shows a causal structure that is not respected by generally covariant equations. Similarly, the world as we experience it shows a temporal direction which is not respected by time reversal invariant equations including the generally covariant equations of interest to Hilbert; the relationship between generally covariant fundamental equations, statistical mechanics, and experienced time irreversibility, viewed as an epistemological problem, is a further theme running through Hilbert's lectures. Once again, Sauer and Majer provide a detailed and helpful introduction to the materials.

In "Principal Questions of Modern Physics" (418), Hilbert contrasts the pace of change and discovery over the preceding 400 years, from Copernicus forward, with the rapid and stunning changes taking place since around 1890 (beginning with the

discovery of Hertzian waves), and the way in which new theoretical and experimental developments came one after the other pushing one another forwards. We have all these new experimental discoveries on the one hand, showing us the reality of even atoms and molecules, and on the other hand, we have our ever more complex frameworks of concepts which we can build using logic, but, says Hilbert, the question remains of whether these logical constructions apply to reality (419). The epistemological problem here concerns the relationship between the world as it is thought by us, characterized for Hilbert by the "world equations" (and specifically the generally covariant field equations of physics), and the world as it is experienced by us. In practice, the applicability of many laws of physics is achieved via additional principles, termed "accessorial laws" by Hilbert. However, Hilbert argues that in principle no such accessorial laws are needed for the fundamental "world equations" of physics. Sauer and Majer (381) summarize the argument, which involves use of Hilbert's axiomatic method and a claim about one-to-one mapping. This argument, along with the final pages of this same set of lecture notes, offers rich and (to my knowledge) largely unexplored resources for those interested in early twentieth-century HOPOS.

Let me say a few words about what is in these final pages (424–432). Here, Hilbert discusses the role of the a priori in our knowledge of reality. He offers his criticisms of Kantian epistemology and Poincaré's conventionalism in light of the developments in physics and geometry of the late nineteenth and early twentieth century, and he sets out his own position. He does so with a colorful and entertaining vivacity that is entirely missing from my brief summary that follows. While accepting the need for a priori elements in our theorizing of reality, Hilbert argues Kant's position must be revised, both with respect to the role of the a priori in our theorizing and with respect to its reach, which Kant drastically over-estimated. Hilbert argues that one lesson from recent developments is that we must be extremely cautious about the a priori elements that we adopt in our theorizing: things that we may not even recognize explicitly may later turn out to be shown unwarranted (as has been the case with absolute simultaneity, for example). Hilbert describes the way in which the place of geometry with respect to physics, and with respect to other branches of mathematics, has been altered by developments in both mathematics and physics. We must be cautious, then, and recognize that we remain in the process of uncovering and removing unwarranted a priori elements. His axiomatic method is a key tool in this process. Hilbert rejects Poincaré's conventionalism, arguing that it is responsible for significant confusion, and offers his own account of the status of a priori elements in theorizing. There is much more in these pages, such as Hilbert's separation of the question of the epistemological status of laws of nature from the question of their exactness, but I hope this flavor will be sufficient to encourage more people to take a closer look.

Chapter 5 contains Hilbert's 1912 lectures on radiation and quantum theory, while chapter 6 contains his much later lectures, first (1922/23) on the "old" and then (1926/27) also the "new" quantum theories. As with his work on generally covariant physics, we see Hilbert's serious engagement with conceptual and philosophical aspects of the new quantum theory. The 1926/27 course is related to

the co-authored paper "Foundations of Quantum Mechanics" by Hilbert, von Neumann, and Nordheim.

Philosophers of physics and those with interests in early twentieth-century HOPOS will find in this book an irresistible invitation to explore Hilbert as philosopher of physics and epistemologist. We should all look forward to seeing the work that this book provokes on Hilbert, on Hilbert and his contemporaries, and on the issues that Hilbert engaged with that remain alive and with us today.