The Structure (and History) of "Scientific Revolutions"

Personal essay

> *If science is the constellation of facts, theories, and methods collected in current texts, then scientists are the [people] who, successfully or not, have striven to contribute one or another element to that particular constellation.*
>
> T. Kuhn, (1962). *The Structure of Scientific Revolutions*.

The term 'paradigm shift' was coined by Kuhn in his 1962 monograph, *The Structure of Scientific Revolutions*. Kuhn explains that when science experiences a "crisis" – a failure of the existing theories to solve unanswered problems – the scientific community is forced to re-evaluate its foundational approach to the questions at hand. A paradigm shift occurs when this results in a widespread adoption of a completely new foundational perspective, and this marks a scientific revolution.

Although I am not a Kuhnian, it seems clear that twentieth century physics saw two scientific revolutions with the development of relativity theory and quantum mechanics. My collection aims to record these revolutions and the events that surrounded them, from the 19th century crises that prompted them to their consequences through the information age.

My interest in book collecting began in 2011 when I befriended a professor who introduced me to the rare book community. This happily coincided with two important factors. The first was a growing desire to find a hobby that would allow me to explore my admiration for rare and important objects. Although I had always enjoyed the idea of collecting antiques of some kind, I had never felt that I was in a position to properly appreciate their historical value. The second was my research in early modern logic and the philosophy of physics, which had led me to carefully read early twentieth century texts in both fields. In the case of modern logic these texts were the objects of my studies and so I immediately grew to appreciate their roles in the history of scientific thought. In philosophy of physics my concentration on these texts was somewhat indirect. I had been struggling to find a textbook that adequately covered certain details of quantum theory, and by chance I borrowed a copy of Dirac's *Principles of Quantum Mechanics*. I quickly read through the book and found Dirac's writing to be uniquely clear and precise – much more so than anything else I had read. This immediately led me to examine other texts from the same period, many of which are now central pieces in my collection.

I spent the 2012-2013 academic year as a visiting scholar in London, and it was here that I fully embraced my passion for rare book collection. I was curious to find out how much it would cost to buy a first edition of Dirac's *Principles* and was surprised to learn, first, that it was the first quantum mechanics textbook in English, and second, that first editions are quite scarce. By pure luck, I found someone in the Midlands who was liquidating his small collection, including a bright copy of the Principles as well as a very good first printing of Einstein's *Relativity* (1920) and first edition of Born's *Einstein's Theory of Relativity* in its incredibly rare dustjacket.

This small collection quickly grew between 2014 and 2016 when a family illness limited the attention I could give to my studies. My purchasing was limited to online sales and auctions at this time, but I found that researching rare books made for a somewhat productive distraction. It was then that I properly developed my goal for the collection as well as a strategy to achieve it. Thematically, I divided the collection into three topics that largely parallel my academic interests: mathematics and logic, foundational physics, and philosophy of science. These divisions should not be understood as strong delineations between academic subjects, though. Rather, they are three complementary (and often convergent) directions of inquiry. Indeed, this is reflected by the many authors who appear across multiple topics. For example, Einstein and Bohr were as much philosophers as they were physicists; Russell was both mathematician and philosopher; and Fisher's *Design of Experiments* would likely fall into all three.

Independent of the topic, my acquisition strategy now contains four item categories. First are the publications that define the accepted theories of the twentieth century. Second are publications that detail the scientific crises that preceded these theories or that outline further theoretical developments. Third are manuscripts or letters (and in some cases, publications or association copies) that demonstrate the academic debates and exchange of ideas surrounding the theories' developments. Lastly, fourth are publications that raise sociological considerations about how the history of twentieth century physics has been shaped.

Having established this plan, I began by looking for several important papers from early- and mid-twentieth century physics. I particularly enjoy hunting for items at exceptional prices (be it in a bookshop or online), and because these papers are printed in academic journals they can appear on the market under the journal's title without reference to its contents. I managed to acquire many of these by carefully examining and cross-referencing long lists of individual issues, perhaps most notably a pristine copy of Feynman's (1948) in its incredibly rare single-issue format. This paper appears in *Reviews of Modern Physics*, a journal that focusses on publishing high-quality review papers and graduate student work, which may explain the relative scarcity of issues from before 1950.

Two books that I had hoped to add to my collection from very early on were Frege's *Grundgesetze der Arithmetik* and Whitehead and Russell's *Principia Mathematica*. These mark the foundations of contemporary logic and mathematics, but both books are exceedingly rare (possibly due to poor reception when they were published). It is said that Frege was forced to fund printing of the second volume of the *Grundgesetze* himself, and Whitehead and Russell's work received such poor reviews that only 500 copies of the second and third volumes were printed. (Griffin & Linsky, 2013).

I consider myself very lucky to have successfully acquired first editions of both of these works in 2015 after years of searching. The *Grundgesteze* was offered to me by a graduate student in Israel from whom I had made a few other purchases. Although it was offered only as volume one, I was pleasantly surprised to find that it included both volumes bound together. (And the person from whom I purchased it was happy to hear it as well!)

The *Principia* was an even more fortuitous find. It is a highly sought-after title given its scarcity and importance. (Since I began collecting, I have seen only three complete sets appear on the market – each asking six figures.) I was able to be purchase my set for $1000 from a small dealer in upstate New York merely hours after he posted it on AbeBooks. I recall waking up to see an email alert on my phone and rushing to complete the order before I had even put my glasses on! Although there were some hiccups with the order, and the set does need some repairs, I still clearly remember what it felt like to receive this landmark first edition - something which I truly believed would never appear on my shelves.

Since 2016 my collecting has no longer been limited to online purchases, and I've had the opportunity to spend a fair bit of time in small European bookstores. This has become one of my favorite parts of collecting, as I frequently find obscure and unique items that offer unusual insight into the history of our physics. For example, a small bookshop in Munich held evidence of how a generation of quantum physicists were taught by one of the theory's founders. A short pile of books and papers that had been hidden behind a box of old postcards contained course notes for Werner Heisenberg's class in quantum theory from the late 1950's/early 1960's. Heisenberg was the leading figure in the first formulation of quantum mechanics in 1925, and these notes provide insight into how he saw the theory approximately 35 years later, after the subsequent reformulations by Schrödinger (1926) and Feynman (1948).

One of the most exciting of these obscure items was Geertruida de Haas-Lorentz's short monograph on *The Theory of Quanta*, which had been sitting near the top of a tall bookshelf in central Berlin. It was the name 'Lorentz' that first caught my eye – Hendrik Lorentz was an important physicist in the early 20th century. However, noting that the first name was a woman's I recognized that this was a unique piece. Geertruida, I learned, was Hendrik's daughter and doctoral student, and is one of many women who have largely been relegated to footnotes in science despite their important contributions.

These two items, in fact, represent my vision for the future of my collection. There remain some major publications that I wish to add, but I am now more concentrated on acquiring items that represent the dialogue surrounding quantum physics and relativity theory, and publications by women and minorities who have made significant impacts but who have largely been forgotten.

I am sorry to say that there is no exciting story about how I found a first edition of Kuhn's monograph. I simply purchased it from the same person who sold me my copy of Frege's *Grundgesetze*, (albeit at an exceptional price). But even if its acquisition was not particularly exciting, its influence has been tremendous. Objects from my collection (and from my wish list) are not merely books that sit on my bookshelf. They are research tools - resources that have inspired new ways of examining contemporary physical science, which in turn has resulted in new approaches to answering current questions in philosophy of physics.

Highlights from the Collection

The following represents a few my most prized items. They are divided into three topics, as outlined above, and are listed chronologically. Articles in complete journal volumes are listed with volume number and pagination, and articles in individual issues include issue number as well. Title translations are those used in later English versions where possible, and are my own where no translation exists. All publications are first editions and first printings.

As my collection is held in two places (my apartment in Brooklyn and my father's home in Montreal), I am unfortunately unable to provide photographs of all items listed here.

SELECTIONS IN MATHEMATICS AND LOGIC

1892 Gottlob Frege

Über Sinn und Bedeutung [On Sense and Reference]

Zeitschrift für Philosophie und philosophische Kritik, *100*, pp. 25-50.

Arguably Frege's most important article, "On Sense and Reference" describes what has become called the *Frege Puzzle*. Frege considers the difficulty of identity statements given that the meaning of what we say depends only on the referents of our utterances. If Mark Twain and Samuel Clemens refer to the same person, then it isn't clear how the sentence "Mark Twain is Samuel Clemens" can be any more informative than the sentence "Samuel Clemens is Samuel Clemens" Frege explains that language use involves two semantic levels; the referents of "Mark Twain" and "Samuel Clemens" may be the same, but their *senses*, or how this referent is mentally represented by speakers, can differ. (Zalta, 2019).

Frege was the first who sought to formalize the contents of propositions, and his invention of quantified predicate logic is often seen as offering the first major advance in logic after Aristotle and the ancient Greeks. This article is standard reading for philosophy students today.

Notes: Library bound volume in very good condition including journal contents for 1891 and 1892. The first two leaves of Frege's article are attached at the spine and the first leaf is somewhat discolored. I consulted with Cara Schlesinger (of Faenwyl Bindery) and she believes the page was torn out at some point and later repaired, but is confident the page is original. This is the only copy of this article that I have seen on the market since I began collecting.

1893, 1903 Gottlob Frege

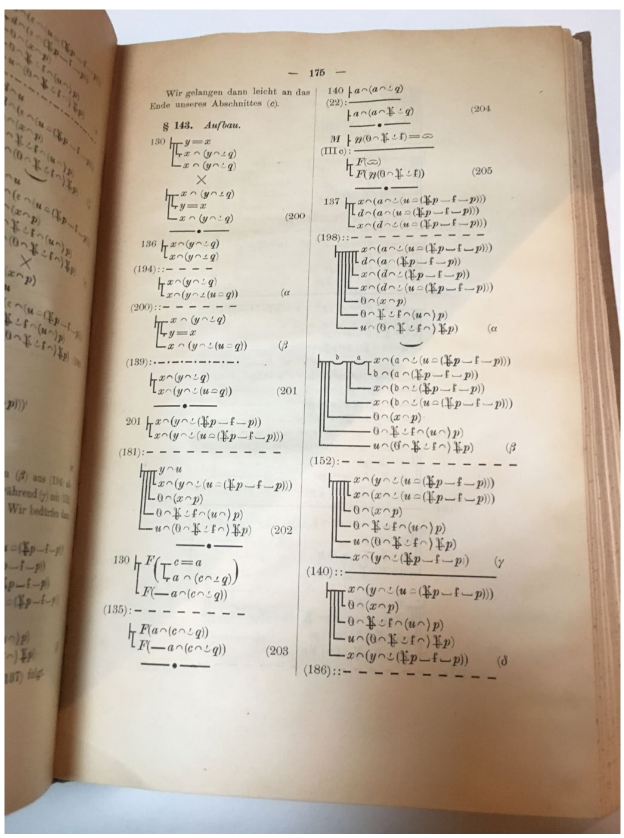
***Grundgesetze der Arithmetik* (*Basic Laws of Arithmetic*), vols. 1 & 2**

Jena: Verlag Hermann Pohle.

Often called his opus, the *Grundgestze* presents Frege's argument against Kant's claim that mathematics is synthetic (as compared to analytic, or purely logical). The argument is laid out in Frege's *Begriffsschrift*, or "thought-writing," which was a two-dimensional formal system invented by Frege in the 1870's. (Zalta, 2019). It is said that this system was not only tremendously difficult to read, but even worse to type-set. This, combined with the poor reception of the first volume of the *Grundgesetze,* meant that Frege had to fund the printing of the second volume humself.

Shortly before the second volume was ready to go to press, Frege famously received a letter from Bertrand Russell. This letter contained *Russell's Paradox*, an inconsistency within Frege's system that Russell had discovered. A response to the letter appears as an appendix to the second volume of the *Grundgesetze*, but Russell's Paradox ultimately proved fatal to Frege's system. (Zalta, 2019).

Notes: Two volumes bound together in library binding with usual stamps from Birkbeck Univeristy in London. Some water damage throughout, but not touching any of the text. I have seen only one other copy of the Grundgesetze on the market in at least five years.



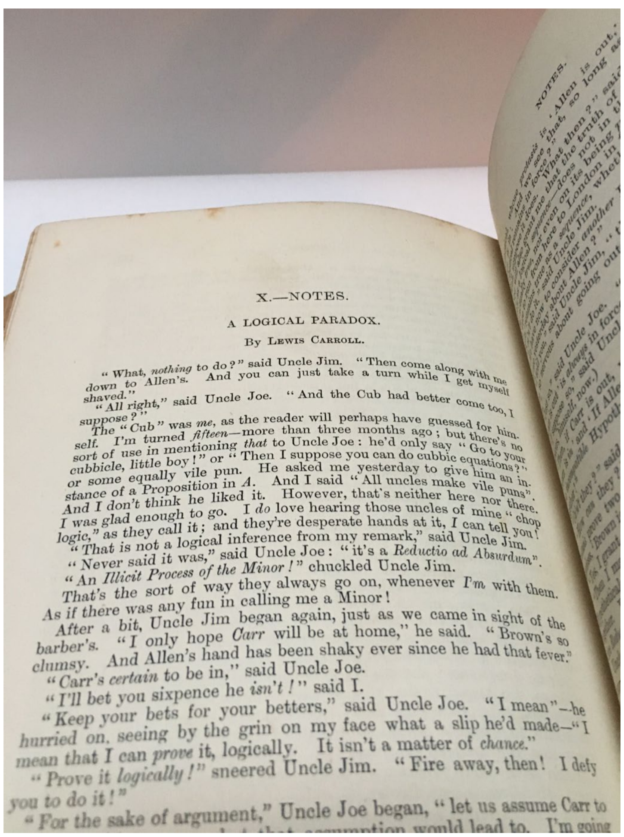
Frege, 1893/1903.

1894, 1895 Lewis Carroll [Charles Dodgson]

A logical paradox
and
What the tortoise said to Achilles
Mind, *3*, pp.436-438, and *4*, pp. 278–280.

These two papers may be the only two academic pieces published under the name Lewis Carroll, and are almost certainly Dodgson's most well-known. The first paper presents Carroll's "barbershop paradox," now a standard semantic paradox that one encounters in the literature (though its source is often overlooked!). In the latter, Carroll notes that the foundational tools of deduction (upon which all logic since Aristotle has been based) are highly questionable. (Braithwaite, 1932). In 1995, Mind reprinted the latter for its centennial with a contemporary response.

Notes: Both volumes are in very good condition in library bindings with standard library stamps. Mild foxing at the edges throughout both volumes.



X.—NOTES.

A LOGICAL PARADOX.

BY LEWIS CARROLL.

"What, *nothing* to do?" said Uncle Jim. "Then come along with me down to Allen's. And you can just take a turn while I get myself shaved."

"All right," said Uncle Joe. "And the Cub had better come too, I suppose?"

The "Cub" was *me*, as the reader will perhaps have guessed for himself. I'm turned *fifteen*—more than three months ago; but there's no sort of use in mentioning *that* to Uncle Joe: he'd only say "Go to your cubbicle, little boy!" or "Then I suppose you can do cubbic equations?" or some equally vile pun. He asked me yesterday to give him an instance of a Proposition in *A*. And I said "All uncles make vile puns". And I don't think he liked it. However, that's neither here nor there. I was glad enough to go. I *do* love hearing those uncles of mine "chop logic," as they call it; and they're desperate hands at it, I can tell you!

"That is not a logical inference from my remark," said Uncle Jim.

"Never said it was," said Uncle Joe: "it's a *Reductio ad Absurdum*".

"An *Illicit Process of the Minor!*" chuckled Uncle Jim.

That's the sort of way they always go on, whenever *I'm* with them. As if there was any fun in calling me a Minor!

After a bit, Uncle Jim began again, just as we came in sight of the barber's. "I only hope *Carr* will be at home," he said. "Brown's so clumsy. And Allen's hand has been shaky ever since he had that fever."

"*Carr's certain* to be in," said Uncle Joe.

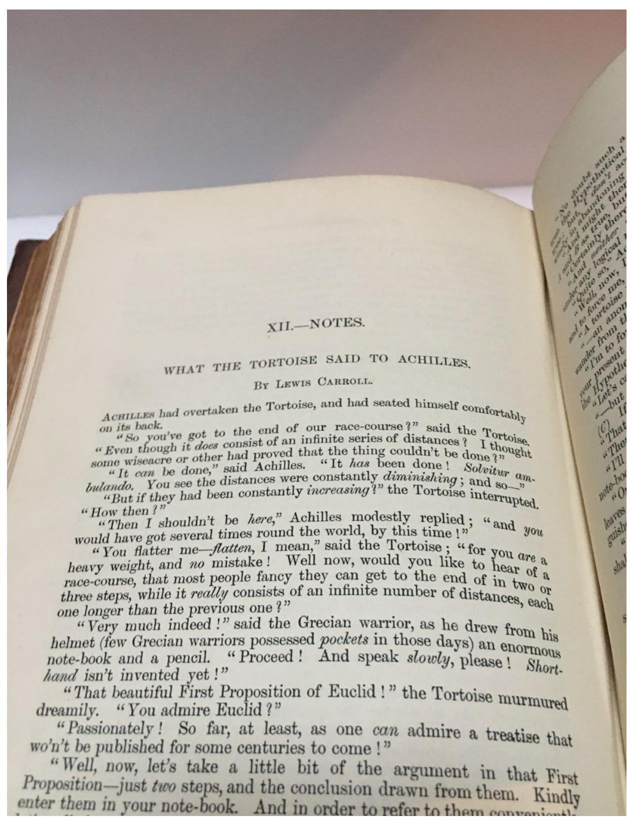
"*I'll bet you sixpence he isn't!*" said I.

"Keep your bets for your betters," said Uncle Joe. "I mean"—he hurried on, seeing by the grin on my face what a slip he'd made—"I mean that I can *prove* it, logically. It isn't a matter of *chance*."

"Prove it *logically!*" sneered Uncle Jim. "Fire away, then! I defy you to do it!"

"For the sake of argument," Uncle Joe began, "let us assume Carr to

Carroll, 1894.



XII.—NOTES.

WHAT THE TORTOISE SAID TO ACHILLES.

BY LEWIS CARROLL.

ACHILLES had overtaken the Tortoise, and had seated himself comfortably on its back.

"So you've got to the end of our race-course?" said the Tortoise. "Even though it *does* consist of an infinite series of distances? I thought some wiseacre or other had proved that the thing couldn't be done?"

"It *can* be done," said Achilles. "It *has* been done! *Solvitur ambulando.* You see the distances were constantly *diminishing*; and so—"

"But if they had been constantly *increasing*?" the Tortoise interrupted. "How then?"

"Then I shouldn't be *here*," Achilles modestly replied; "and *you* would have got several times round the world, by this time!"

"You flatter me—*flatten*, I mean," said the Tortoise; "for you *are* a heavy weight, and *no* mistake! Well now, would you like to hear of a race-course, that most people fancy they can get to the end of in two or three steps, while it *really* consists of an infinite number of distances, each one longer than the previous one?"

"Very much indeed!" said the Grecian warrior, as he drew from his helmet (few Grecian warriors possessed *pockets* in those days) an enormous note-book and a pencil. "Proceed! And speak *slowly*, please! *Shorthand* isn't invented yet!"

"That beautiful First Proposition of Euclid!" the Tortoise murmured dreamily. "You admire Euclid?"

"Passionately! So far, at least, as one *can* admire a treatise that wo'n't be published for some centuries to come!"

"Well, now, let's take a little bit of the argument in that First Proposition—just *two* steps, and the conclusion drawn from them. Kindly enter them in your note-book. And in order to refer to them conveniently

Carroll, 1895.

1910, 1912, 1913 Alfred North Whitehead and Bertrand Russell

***Principia Mathematica*, vols. 1-3**

Cambridge: Cambridge University Press.

While Frege was working on his *Grundgesetze*, Whitehead and Russell were individually composing their own works on the foundations of mathematics. Whitehead's *Treatise on Universal Algebra* and Russell's *Principles of Mathematics* were each meant to see a second volume, but when the two realized that their work heavily overlapped, they instead came together to produce the *Principia Mathematica*. (Griffin & Linsky, 2013). Like Frege, Whitehead and Russell aim to prove that mathematics could be seen to follow from pure logic. However, their system avoided Russell's paradox and expanded the thesis to investigate further implications.

The *Principia* is seen as one of the most influential texts in mathematics and modern logic, yet its first printing was notoriously small. The three volumes were printed individually over four years. However, following tremendously poor reception of the first volume (which was printed in a run of 750 copies in 1910), volumes two and three saw only 500 copies each in 1912 and 1913, respectively. (Griffin & Linsky, 2013). The importance of the work must have been noticed in the decade that followed, as the second edition of 1925 has been reprinted regularly.

Notes: Since 2013 only three complete sets have appeared on the market, each costing at least $100 000. I have tried to purchase as many copies of individual volumes as possible over the years in hopes that I can one day form a complete set in fine condition. (Note that because the volumes were published individually there are no truly 'married' sets.) To date, I have one complete ex-library set in original binding in poor to good condition. The spine of Volume 1 is torn and partially missing, but volumes two and three see only slight tearing to the heads and feet of the spines. All three have standard library stickers and stamps. Internally, title pages are lacking and there are minor chips to pages in all three volumes, though volume one is significantly more damaged than the others. (Chipped pieces are present and will soon be repaired.) I have confirmed that these are all first editions by collating against WorldCat information for first and second editions. In addition to this set, I have three other copies of volume one, including one in library binding, one in very fine condition, and one in good condition. I also have one copy of volume two in library binding, but its signatures have been trimmed at the spine in the binding process. The included photo shows the volume one in good condition and volumes two and three of the ex-library set.

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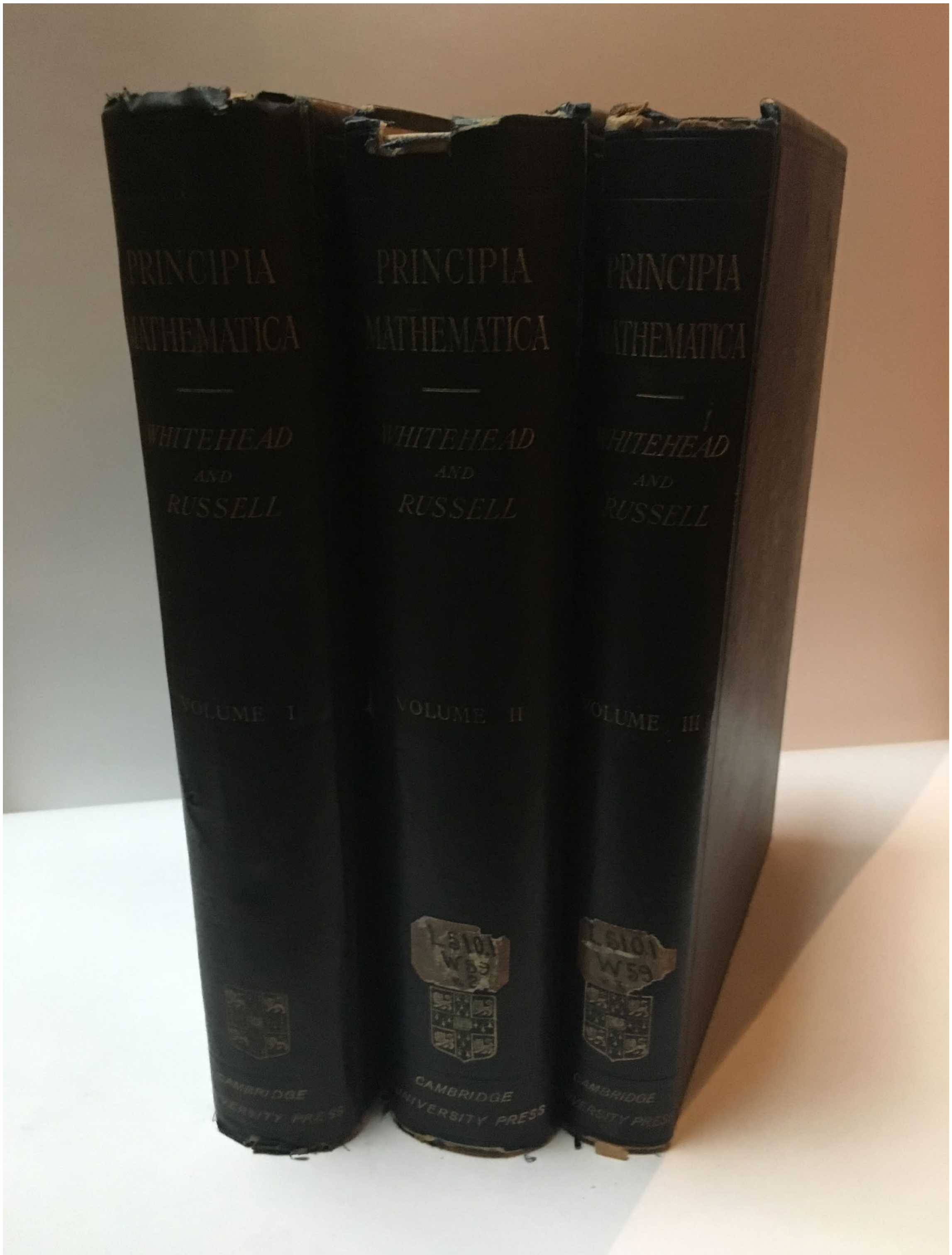


Whitehead and Russell, 1910, 1912 and 1913.

1931 Kurt Gödel

Diskussion zur Grundlegung der Mathematik am Sonntag, dem 7. Sept. 1930

[Discussion on the Foundation of Mathematics on Sunday, Sept. 7, 1930]

Erkenntnis, 2(2-3) (identically *Annalen der Philosophie, 10*(2-3)), pp. 135-151.

Russell's paradox was the first in a long line of results that led to the "Foundational Crisis in Mathematics" in the early twentieth century. The `crisis' here was that mathematics lacked a solid philosophical grounding, and a number of solutions were proposed, from intuitionism, to set-theoretic axiomatizations, to further logical analysis in the vein of Frege and Whitehead & Russell. One such proposal was David Hilbert's, which sought a finite set of provably consistent axioms of mathematics. The program saw significant advancement until Gödel, in 1931, showed that such an axiomatization was impossible. In brief, his first incompleteness theorem proves that any axiomatized formal language that is strong enough to describe arithmetic is necessarily also strong enough to describe a true formula that cannot be proven by the axioms. This result would immediately lead to his second incompleteness theorem, which proves that the consistency of such a language cannot be proven within the language itself.

Gödel famously published his incompleteness theorems in 1931, but this was not the first time that his results appeared in print. He presented his results at the second *Conference on Epistemology of the Exact Sciences* in Königsberg in 1930, where they were discussed with attendees. (Dawson, 1984a, 1984b). This issue of *Erkenntnis*, which published the papers and discussions from this meeting, including those surrounding Gödel's results, appeared prior to Gödel's 1931 papers.

This issue also contains important works by Heyting, Carnap and von Neumann, as well as papers by Reichenbach, Heisenberg and others.

Notes: This is one issue of a complete original run of *Erkenntnis* (1930-1938) in original wrappers. Binding and wrappers are in very good condition with only minor bumping at the corners and head and foot of the spine. However, the text block is somewhat stiff, either due to age or minor (and uniform) water/humidity damage. There is no discoloration and the text is clear.

Upload your bibliography and essay here.

Gödel, 1931.

SELECTIONS IN FOUNDATIONS OF PHYSICS

1919 Geertruida de Haas-Lorentz [Hendrik Antoon Lorentz]

***Theorie der Quanta* [*The Theory of Quanta*]**

Leiden: N.V. Boekhandel en Drukkerij, Voorheen [formerly] E.J. Brill.

This monograph is unique in two ways: First, it represents one of the only publications on the theory of the quanta following the famous 1911 Solvay conference. (See 'wish list' below.) After this point it seemed that Einstein's theory of photons 'took over' and the Bohr-Sommerfeld quantization project began without any consideration for its ontological consequences. Second, it is one of the few publications of Geertruida Haas-Lorentz, daughter and doctoral student of Henrik Lorentz, who was quite famous at the time. (Einstein's special relativity, for example, depends on *Lorentz transformations*, named for Henrik.) Interestingly, the monograph is typically listed as authored by both Hendrik Lorentz and Geertruida Haas-Lorentz. However the cover seems to indicate Geertruida as sole author and Henrik Lorentz as editor of the series in which it appears.

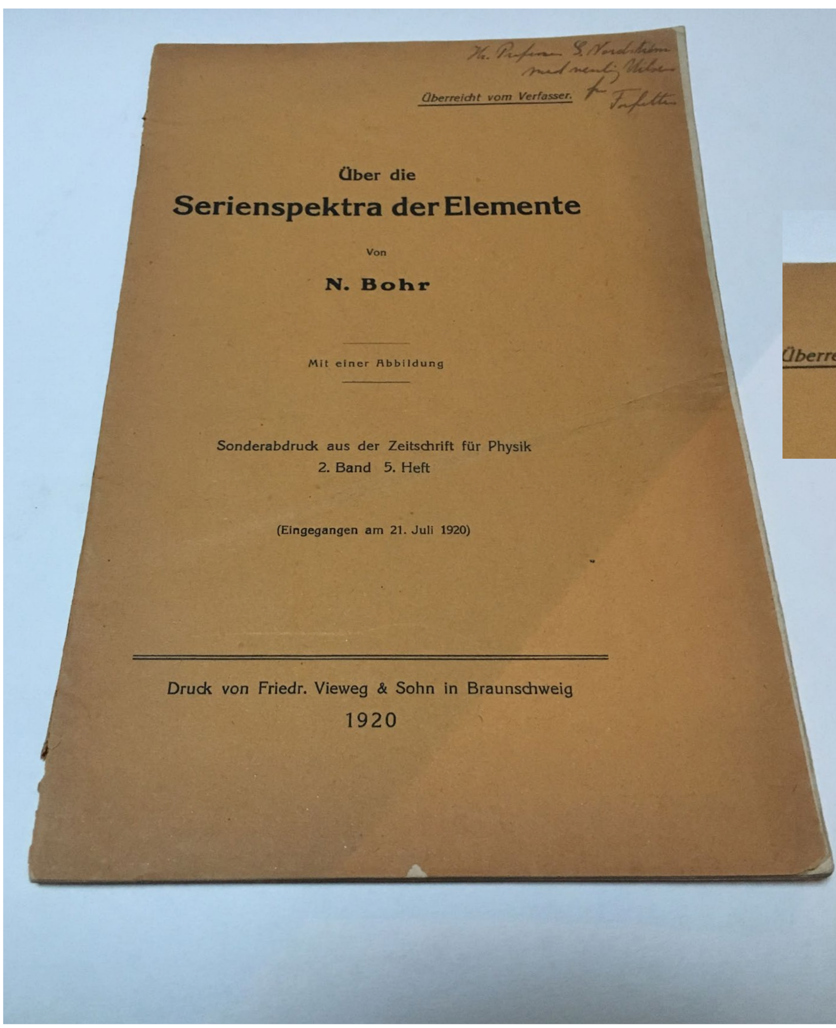
I am in the process of further researching this piece, as it seem that very little has been written about it and it has not been translated. (Guido Bacciagaluppi and Elise Crull, philosophers at Utrecht University and City College CUNY, respectively, have generously offered to help me with this.)

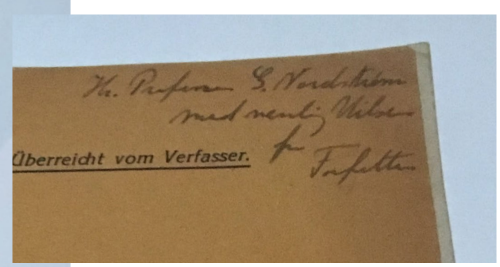
Notes: Fine condition, bound in clear and crisp paper wrappers. Some bumping to corners but clear text throughout.

1920 Niels Bohr [Gunnar Nordström]
Über die Serienspektra der Elemente [On the spectral series of the elements]
Offprint from *Zeitschrift für Physik*, *2*(5), pp. 423–478.

Unlike the case of Einstein's theories of relativity, where it is clear why relativistic effects are not typically observed at our size and energy scale, it remains unclear how quantum theory fits into our experience. Early attempts to solve this problem relied on finding the "classical" limit of quantum mechanics - scales where quantum effects 'wash out' in some way. Bohr, a central figure in this project, described how the two theories should connect in what has become known as the *correspondence principle*. Although the concept had been mentioned prior to this publication, this marks the first time Bohr used the term in print, (Nielsen, 1976), and is thus one of the most important pieces of foundation quantum mechanics to appear before 1925.

Notes: Presentation copy of this rare offprint in original wrappers, including the standard *Zeitschrift für Physik* "Überreicht vom Verfasser" ("presented from the author") stamp and a handwritten note addressed to Gunnar Nordström, a renowned Finnish physicist. There is a large, but light crease in the bottom half of the front cover and some minor chips and tears to wrappers.





Bohr, 1920.

1920 Albert Einstein (Robert Lawson, trans.)

Relativity, the Special and the General Theory
London: Methuen & Co. Ltd..

In the same year that he published his general theory of relativity, Einstein released this this short book in German explaining his special and general theories to the layperson. Its success is evident in that it had seen at least 14 editions by 1922. This is the first English edition, translated from the fifth German edition. (Schlipp number: 130)

Although relatively common, this book demonstrates the tremendous popularization of Einstein's theories. Within a few year this would be translated into many languages, including French, Italian, Russian, and even Yiddish.

Notes: Very good condition, though lacking the rare dustjacket. Boards are bright and binding is tight. Some foxing at front and rear endpages and title page.

1922 Max Born (Henry Brose, trans.)

Einstein's Theory of Relativity
London: Methuen & Co. Ltd..

This popular textbook on Einstein's theory was written by one of the three 'fathers' of quantum theory, and is frequently hailed as a clear and accessible text that brings the reader from classical to relativistic physics. This copy includes the exceptionally rare dust jacket, which I have only seen on the market once since purchasing this in 2013.

Notes: Fine to very fine copy of this first edition text. The bind it tight and boards are well attached. Some very, very slight warping to the boards, but this is barely noticeable. The dusjacket is in very good condition with very minor bumping to the edges and very slight sunning to the spine.

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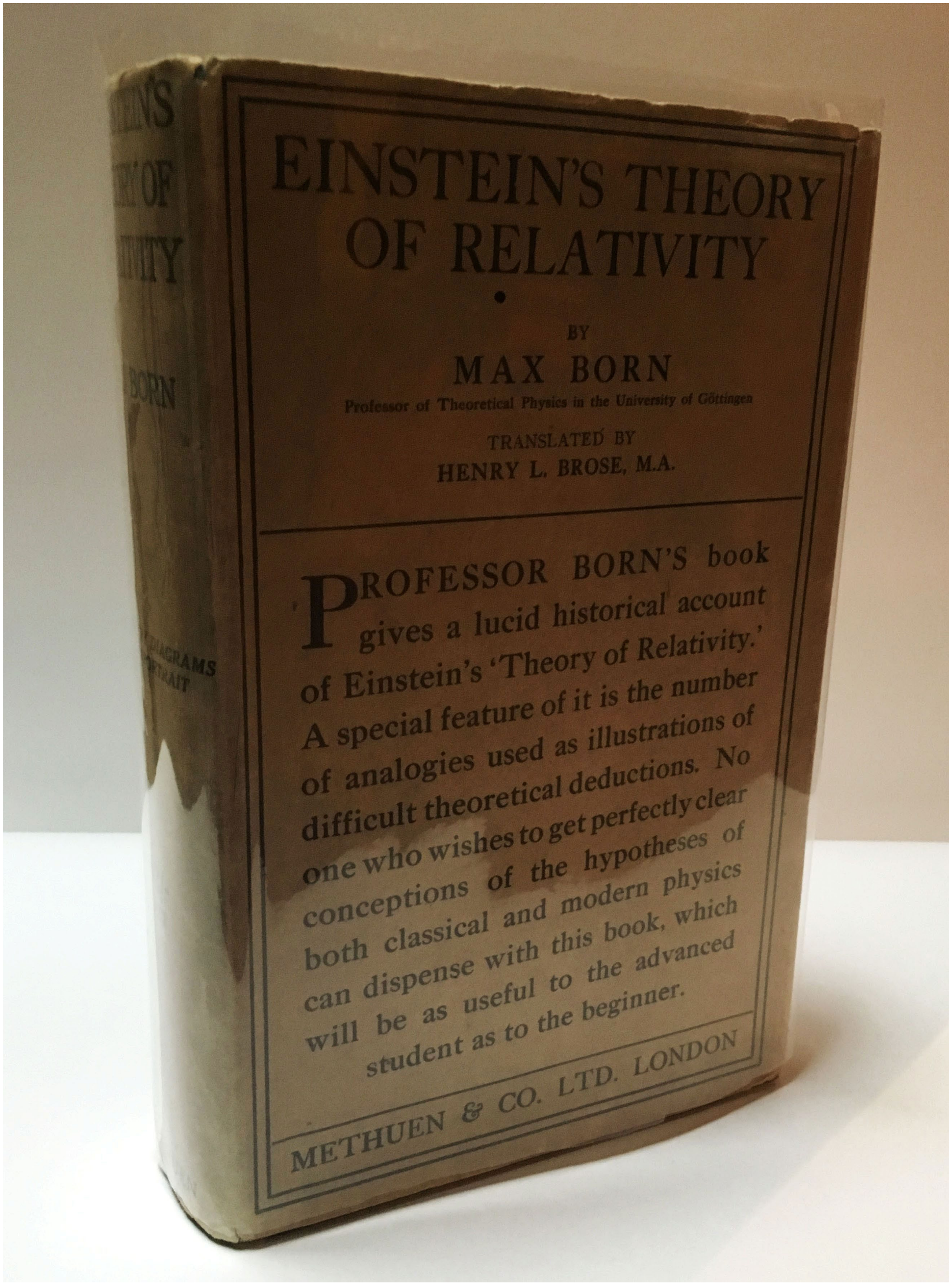
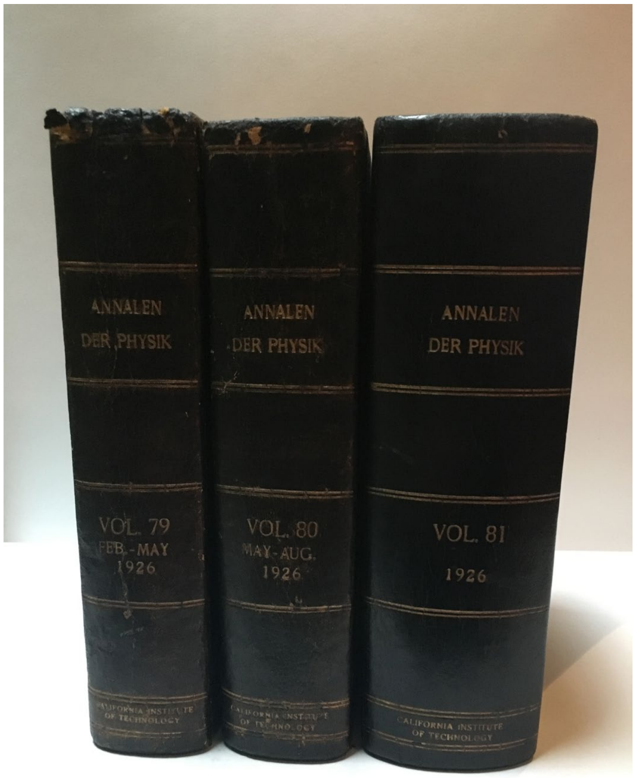


Born, 1922.



Schrödinger, 1926.

1926 Erwin Schrödinger
Quantisierung als Eigenwertproblem
[Quantization as an Eigenvalue problem] I-IV
Annalen der Physik, *79*, pp. 361-376,
79, pp. 489-527,
80, pp. 437-490,
and *81*, pp. 109-139.
And
Über das Verhältnis der Heisenberg-Born-Jordanschen Quantenmechanik zu der meinen
[On the realtionship between Heisenberg-Born-Jordan quantum mechanics and my own]
Annalen der Physik, *79*, pp. 734-756.

Note that these volume numbers refer to the fourth series (*vierte Folge)* of *Annalen der Physik*. They are sometimes listed as volumes 384, 385 and 386 of the journal's entire run.

In 1925, Heisenberg, Born and Jordan published the "Three man paper", which marked the completion of the first formalization of quantum mechanics. This was Heisenberg's third paper on the subject that year, who had worked to develop this formulation using matrix algebra. In the year that followed, Schrödinger's four-part "Quantisierung als Eigenwertproblem" presents an alternative formulation of the theory using wave mechanics. In second paper listed here, "Über das Verhältnis der Heisenberg-Born-Jordanschen Quantenmechanik zu der meinen," Schrödinger proves that the two formulations are equivalent.

Both Heisenberg's and Schrodinger's formulations are commonly used today. However, it is Schrödinger's equation, presented in the first part of "Quantisierung als Eigenwertproblem", which is now almost synonymous with "quantum dynamics."

Notes: These leather-bound volumes are ex-library from the California Institute of Technology (with usual stamps), which is one of the most important physics institutions of the 20th century. Volumes 79 and 80 have some damage to the head and foot of the spine. Bindings of volumes 80 and 81 are tight, but there is a weakened hinge in volume 79 coinciding with the first page of the first page of "Quantisierung als Eigenwertproblem." Text blocks are clear with only some mild discoloration throughout.

1928 Paul Adrien Maurice Dirac

The Quantum Theory of the Electron, parts 1 and 2
Proceedings of the Royal Society of London, A, *117*, pp. 610-624,
and *118*, pp. 351-361.

Paul Dirac, one of the key figures during the development of quantum mechanics, was particularly concerned with how the theory might fit with Einstein's relativity. In 1928 this two-part paper laid out the foundations of quantum electrodynamics and relativistic quantum mechanics. "Probably Dirac's greatest contribution to physics," (Kragh, 1990), the paper includes the first appearance of the Dirac equation, which describes relativistic fermions (electrons, quarks, and other massive particles). Dirac's work here would lead directly to his prediction of the existence of anti-matter in 1931. (See below.)

Notes: In early 20th century 3/4 leather library binding from the US Air Force Arnold Engineering Development Complex (AEDC) Technical Library. Binding is tight and text is very clear with only minor markings. Very mild discoloration and bumping to the rear boards where paperclips held library cards in place.

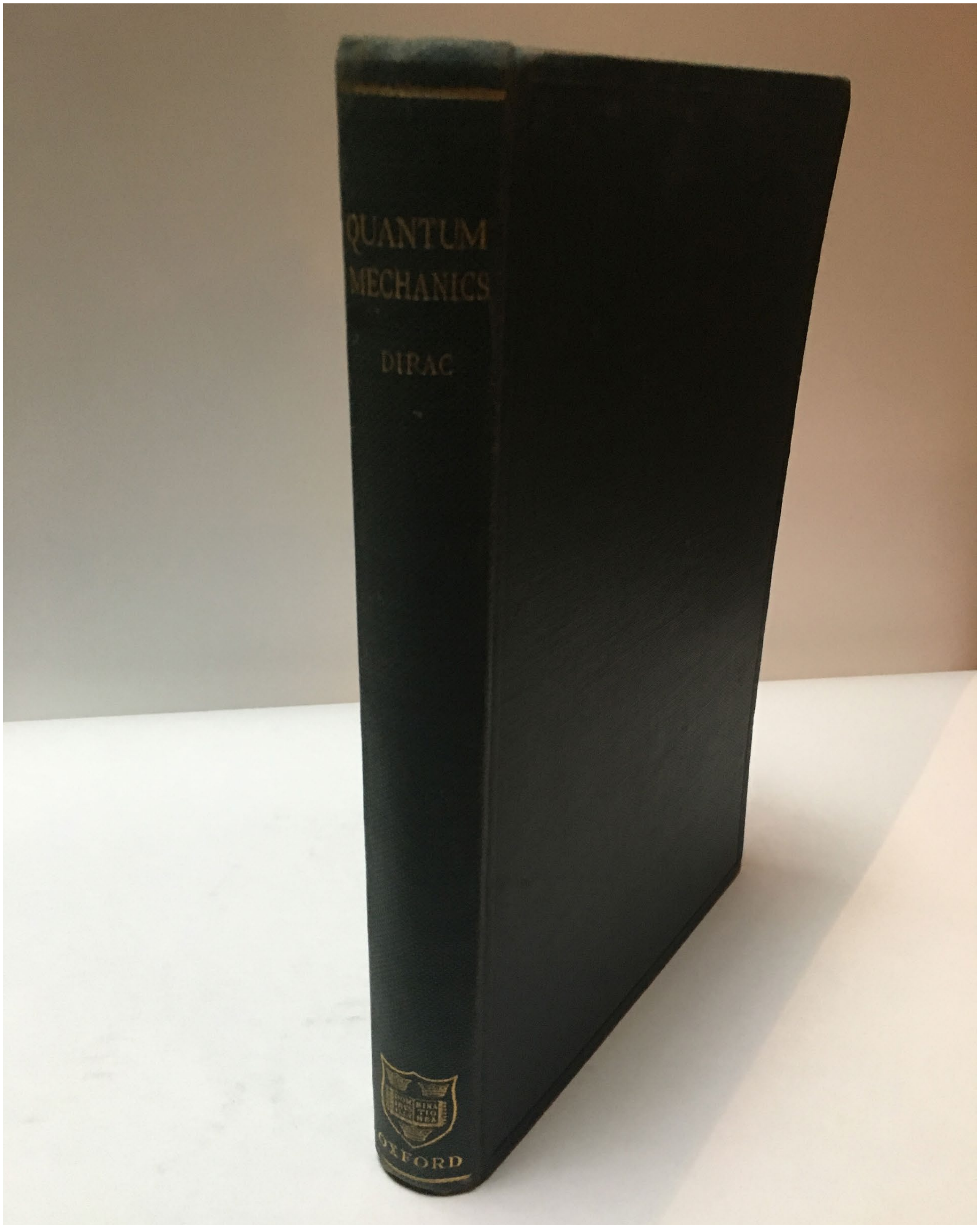
1930 Paul Adrien Maurice Dirac

The Principles of Quantum Mechanics
Oxford: Oxford University Press.

Dirac's *Principles* is the first English textbook in quantum mechanics. Written just five years after the theory had been first formalized, Dirac's text details the connections between fundamental quantum mechanical concepts and the advanced classical mechanics from which it was 'inspired'. The text itself was quite popular, as three further editions and multiple translations would appear over the next decades. (Kragh, 1990).

Notes: Near fine/fine. There is some wear to the head and foot of the spine, but otherwise the boards and spine are exceptionally bright and clear with only a slight black mark on the spine below the title. Binding is tight, as if unread. Corners are very mildly bumped and the text block is as new. (The photo appears to show some warping to the front board, but this is an illusion due to the angle of the photo.)

Upload your bibliography and essay here.



Dirac, 1930.

1931 Paul Adrien Maurice Dirac

Quantized Singularities in the Electromagnetic Field

Proceedings of the Royal Society of London, A, 133, pp. 60-72.

This article marks one of Dirac's most famous results - the prediction of antimatter. Dirac noticed in his 1928 papers listed above that an equation desrcibing the electron had two possible solutions. One solution clearly corresponded the election, but the other - a negative value - had been neglected as a mathematical artefact. Dirac took this value to represent a new type of particle, named here the "anti-electron." (Kragh, 1990).

Today we know that all particles have corresponding anti-particles. Although they are rarely observed because they are quickly annihilated by regular particles, anti-particles play a key role in early cosmology, radiation theory and black hole physics.

Notes: This volume is also from the AEDC library, bound in the same 3/4 leather and in the same condition as those containing Dirac's 1928 paper. Some library sticker remnants appear on the front board. Very mild discoloration and bumping to the rear boards where a paperclip held a library card in place.

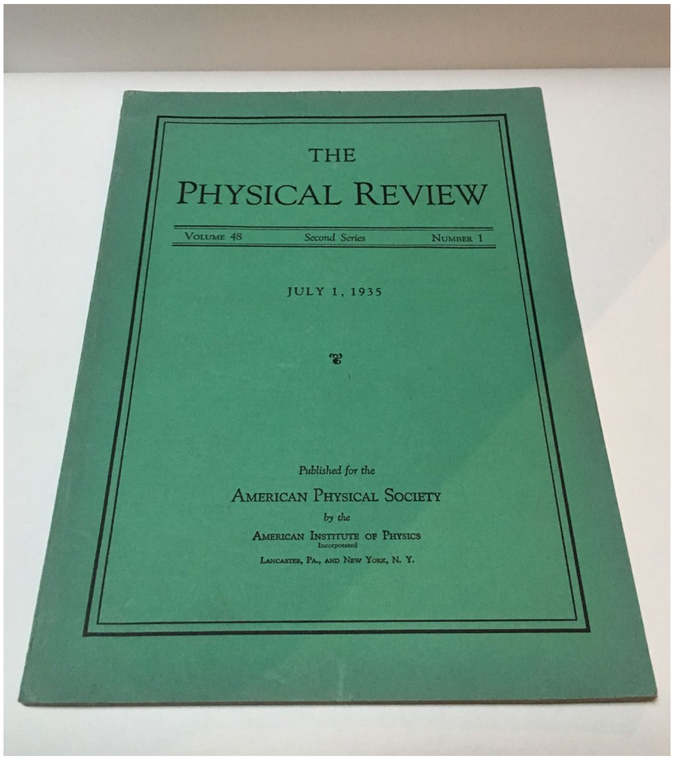
1935 Albert Einstein and Nathan Rosen

The Particle Problem in the General Theory of Relativity

Physical Review, 48(1), pp.73-77.

Having developed the general theory of relativity in 1916, Einstein continued to investigate its consequences well into the following decades. This paper, co-authored with Nathan Rosen, describes the possibility of wormholes in a curved spacetime. They show here that an "Einstein-Rosen bridge," as it has come to be called, can connect two otherwise distant spacetime regions, essentially opening a four-dimensional 'shortcut' between the two. The possibility of Einstein-Rosen bridges is now a very live subject in contemporary spacetime physics (and a common trope in science fiction!).

Notes: It is very rare to find single issues of this journal in original wrappers from the 1930s, and this one is in exceptional condition. Slight discoloration to the wrappers, especially at the bottom of the front wrapper, and some sunning to the spine. Mild bumping to the corners, as is common in single issues from this time.



Einstein and Rosen, 1935.

1937 Albert Einstein and Nathan Rosen

On Gravitational Waves

Journal of the Franklin Institute, 223, pp. 43-54**.**

Einstein first posited the existence of gravitational waves in 1916, shortly after the publication of his theory of general relativity. However, this early work considered only a simplifcation of the Einstein field equations. In 1936, he and Rosen submitted a paper to the *Physical Review* arguing that gravitational waves could not exist in a fully relativistic spacetime. However, the paper's referee, H. P. Robertson, found an error in their work, and a corrected version of the draft (now describing how gravitational waves *could* exist) was published as this paper in the *Journal of the Franklin Institute*. (Cervantes-Cota et al, 2016). This article then marks the beginning of a complete theory of gravitational waves - a theory that would not see experimental verification until the LIGO experiment of 2015.

Notes: A complete, library bound volume of the Journal of the Franklin Institute with exceptionally clear pages for the time.

1948 Richard Feynman

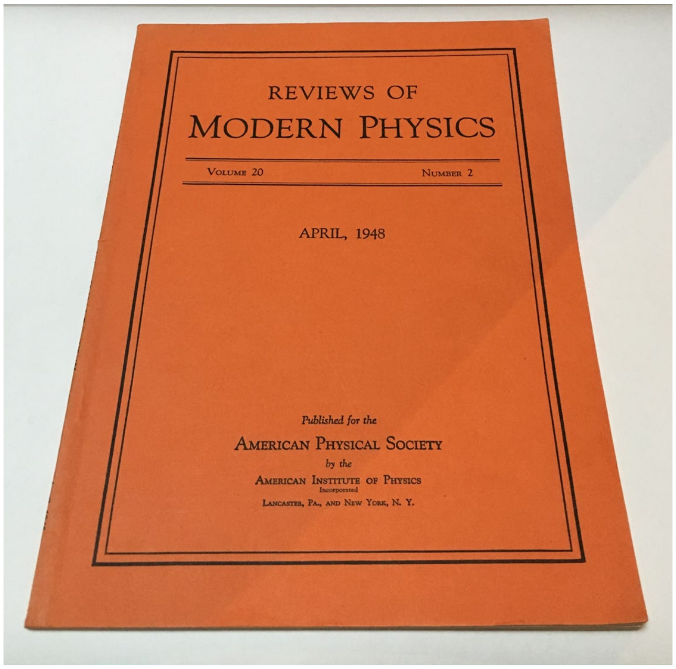
"Space-Time Approach to Non-Relativistic Quantum Mechanics"

Reviews of Modern Physics, 20(2), pp. 367-387.

Richard Feynman's PhD dissertation, published here almost immediately upon its completion, offered the third and final re-formulation of quantum mechanics (after Heisenberg's matrix mechanics and Schrödinger's wave mechanics). This "path integral formulation" has proven invaluable to fundamental physics, opening the door to relativistic quantum mechanics and quantum field theory, which is currently our most fundamental theory. In 1965 Feynman would share the Nobel prize in physics with Sin-Itiro Tomonaga and Julian Schwinger "for their fundamental work in quantum electrodynamics, with deep-ploughing consequences for the physics of elementary particles." (NobelPrize.org).

In a way, Feynman's path integral formulations forced a revisiting of the 'old' quantum theory - the theoretical work that occurred prior to the first formulation of the theory in 1925. This work focused on Planck's 'quanta', which appear as a necessary course-graining in the equation for the energy emission of radiating bodies. In the early 20th century there was significant debate about how to understand this coarse graining, and the first Solvay conference in 1911 was largely devoted to the topic. One camp, spearheaded by Einstein, thought that the appearance of quanta indicates that energy is transmitted in small packets, which we now call photons. An alternative, generally associated with Planck himself, as well as Sommerfeld and others, posited that there was some fundamental constraint on the evolution of quantum states Although the two camps are not, in fact, inconsistent, Einstein's camp seems to have 'won' historically, as there is very little discussion of constraints on dynamical laws beyond about 1916. Although he doesn't offer a full philosophical account, Feynman's path integral formulation, in essence, returns to interpreting quanta as representative of a fundamental 'spreading' a quantum system's dynamical evolution.

Notes: Journal issue in original wrappers in very fine condition. Aside from very slight softening of the corners, this incredibly rare issue appears almost as new. (Japanese printings sometimes come to market, but I have seen only one other copy of this original American printing, and its condition was quite poor compared to this one.)



Feynman, 1948.

1949 John Bardeen and Walter Brattain

Physical Principles Involved in Transistor Action

Bell System Technical Journal, 28(2), pp. 239-77.
and
Physical Review, 75(8), pp. 1208-1225.

There are few experimental consequences of quantum theory as impactful as the development of the transistor, and this would not have been possible without the work done by Bardeen and Brattain. This paper outlines this theoretical work and was so clearly important that it was simultaneously published in the *Bell System Technical Journal* and the *Physical Review*. Bardeen and Brattain along with William Shockley, would win the nobel prize in 1956 "for their researches on semiconductors and their discovery of the transistor effect."(NobelPrize.org).

Notes: Bell System Technical Journal printing: In very fine condition with clean wrappers and tight binding. Spine is very slightly sunned. Slight pencil marking on front wrapper (indicating prior owner's interest). Interior very tight with no markings.

Physical Review printing: Good condition in original wrappers. Some discoloration on front and back wrappers. Spine is sunned with chipping to head and foot and some text worn off. Previous owner's name on top right of front wrapper. Interior is clean and binding is tight.

1951 [John Bardeen]

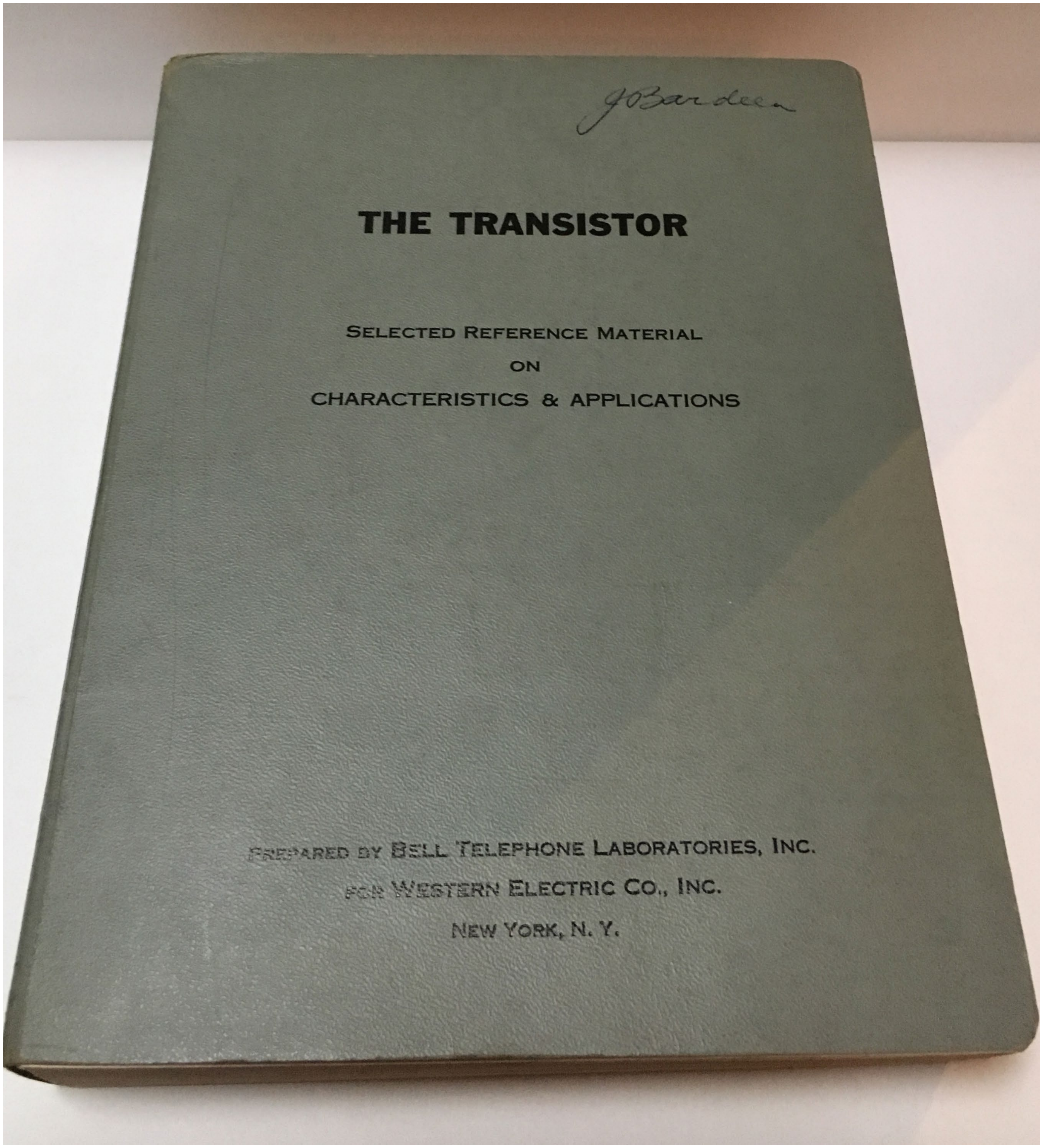
The Transistor. Selected reference materials on characteristics and applications

New York: Bell Telephone Laboratories.

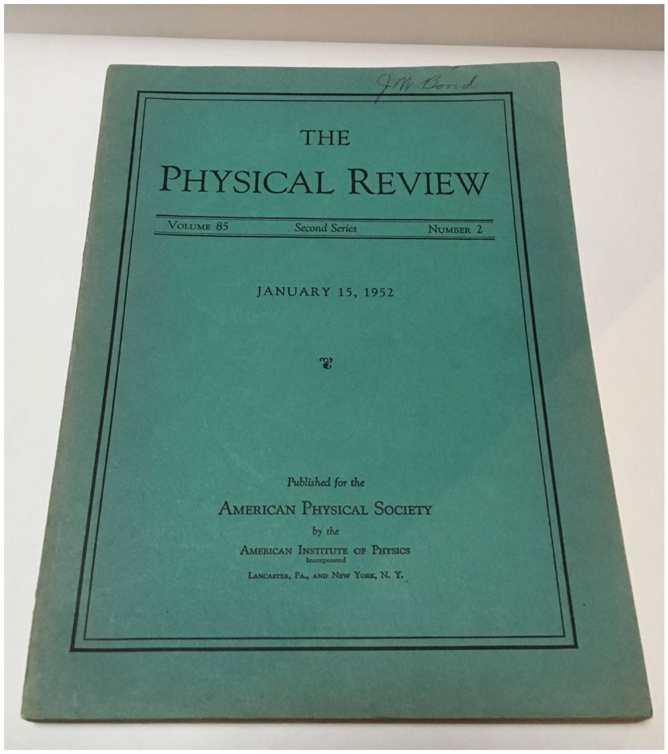
In the same year that mass production of the transistor began, Bell Labs printed this volume of (mostly) reprints of papers on their theory and development. This copy comes from the library of Bardeen, who (as mentioned above) shared the Nobel prize for developing the theory of the transistor. His signature appears neatly on the top right of the front wrapper in blue pen.

Provenance: This was purchased from an estate liquidator via Biblio. The seller was liquidating the library of Richard E. Coovert, who was one of Bardeen's graduate students (having graduated in 1960). Other books purchased with this one bear Coovert's stamp and signature.

Notes: In thick cardboard wrappers (as issued). One weak or broken hinge with some signatures slightly offset from the rest, but otherwise in near fine condition.



The Transistor [Bardeen], 1951.



Bohm, 1952.

1952 David Bohm

A Suggested Interpretation of the Quantum Theory in Terms of 'Hidden' Variables I and II

Both in *Physical Review 85*(2), pp. 166-179 and pp. 180-193.

Just ten years after the development of quantum mechanics, Einstein, Podolsky and Rosen wrote a short paper suggesting that the theory was 'incomplete'. (See my 'wish list'). They believed that the theory left out 'hidden variables', which, if known, would allow for deterministic descriptions of quantum experiments and would explain away the apparent non-locality of quantum physics.

David Bohm was the first to provide a successful hidden variable theory in these papers. Although his theory was not highly accepted at the time (Becker, 2018), Bohmian mechanics now has a strong following by philosophers of physics such as Sheldon Goldstein, David Albert and Barry Loewer.

Notes: Single issue in original wrappers in very good to fine condition. There is slight bumping to corners, and the spine is slightly sunned, but the text and wrappers are clear and unmarked aside from previous owner's name on the top right of the front wrapper.

1957 Hugh Everett, III

'Relative State' Formulation of Quantum Mechanics

Reviews of Modern Physics, 29(3), pp. 454-462.

A few years after Bohm published his theory, Everett developed his 'interpretation' of quantum mechanics. This paper, a published version of his PhD thesis under John Wheeler, outlines the foundation of what is now called the "many worlds" interpretation of quantum mechanics. (Barrett, 2018). Under this interpretation, *all* possible outcomes of quantum interactions occur, each leading to a new 'branch' of the universe. Like Bohm's theory, Everett's theory did not find followers until years later. And like Bohmiach mechanics, Everettian mechanics now sees many important advocates, including David Deutch, Simon Saunders and David Wallace.

Notes: Very fine to near mint condition single issue in original wrappers. The spine, wrappers and internal text have no markings of any kind.

c.1960 Werner Heisenberg

Notes for a course in quantum mechanics

(Transcribed by one of his students. Printed in Munich at the LMU.)

These notes outlines Heisenberg's class on quantum mechanics, presumably during his time as professor at Ludwig Maximilian University (LMU) in the late 1950's or early 1960s. They appear to be notes that were typeset and photocopied for his students to use, and cover what would now be considered an intermediate level quantum physics course.

Printing and edition information is not available, though no mention of other editions of the notes appears anywhere.

Notes: Pages with paper boards bound with paper fasteners. Both the boards and text block are in very good condition, appearing almost as new but for a few bumps at the corners and some discoloration around the fasteners.

1966 John Stewart Bell

On the Problem of Hidden Variables in Quantum Mechanics

with

1966 David Bohm and Jeffrey Bub

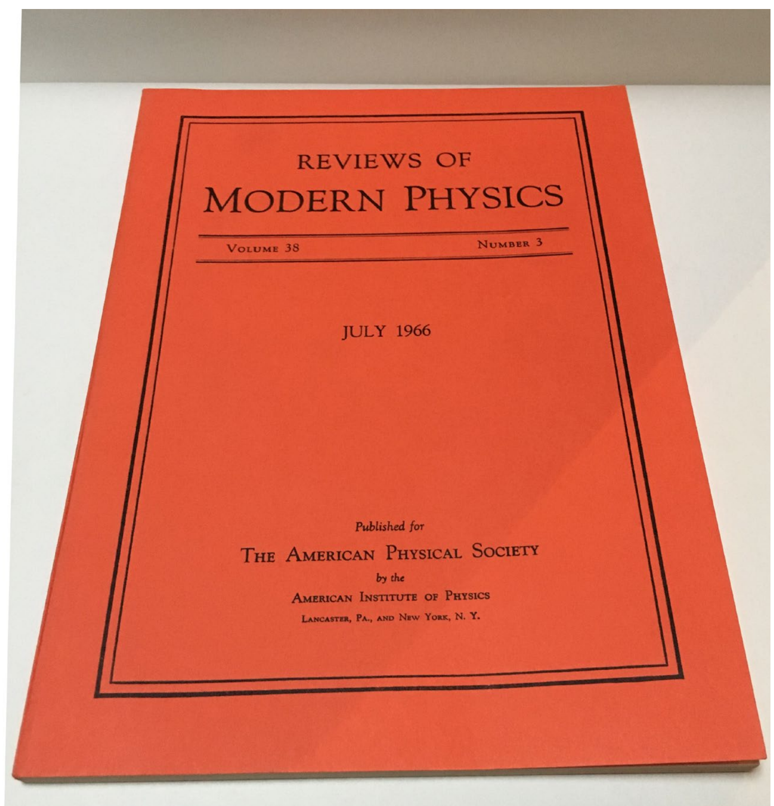
A Proposed Solution of the Measurement Problem in Quantum Mechanics by a Hidden Variable Theory

Reviews of Modern Physics, 38(3), pp. 447-452 and pp. 453-469.

Bell, 1966: The question of whether Einstein, Podolsky and Rosen's picture of hidden variables could be correct was laid to rest by John Bell in 1964 (see wish list) and in this paper in 1966. In this paper, Bell examines prior discussions of hidden variable theories and explains why arguments like that presented in his 1964 require well-defined locality conditions. His work predicts an experimentally verifable distinction between standard quantum mechanics and 'naïve' hidden variables theories that would be used in mutliple experiments between the 1980's and 2016 to prove that Einstein, Podolsky and Rosen were incorrect.

Bohm and Bub, 1966: I include this paper here because of its personal significance. This is the publication of my doctoral supervisor's PhD dissertation under David Bohm. Bub and Bohm here describe a new hidden variable theory, and although the theory was proven incorrect one must admire the irony of its printing immediately following Bell's paper!

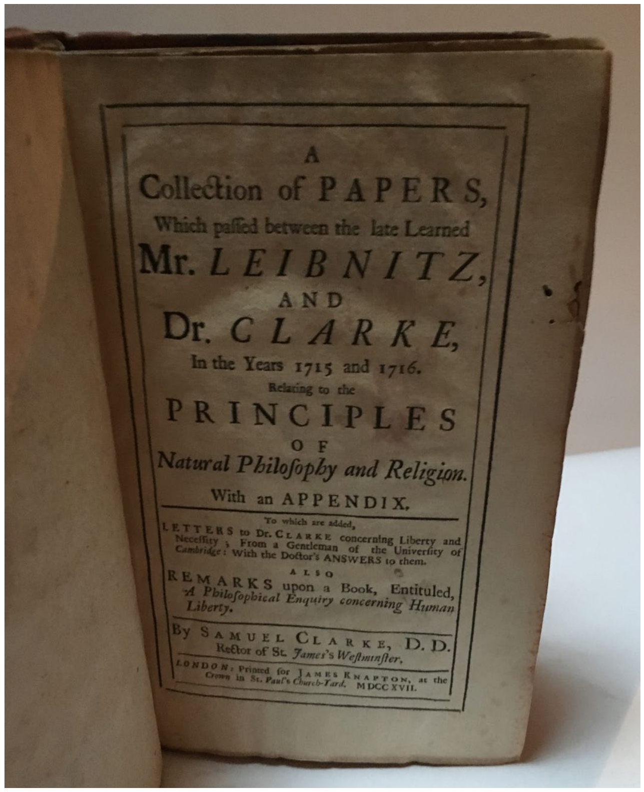
Notes: Single issue in near mint condition with no markings of any kind. There is very minor bumping at the corners, but no other noticeable faults.



Bell, 1966, and Bohm and Bub, 1966.

Upload your bibliography and essay here.

SELECTIONS IN PHILOSOPHY OF SCIENCE



Clarke [and Leibniz], 1717.

1717 Samuel Clarke [and Gottfried Wilhelm Leibnitz]

A Collection of Papers which Passed between the Late Learned Mr. Leibnitz and Dr. Clarke.
[also known as The Leibniz-Clarke Correspondence]
London: James Knapton.

This first edition of the correspondence between Clarke and Leibniz is one of the earliest pieces in the philosophy of space and time. The debate focuses on the independent reality of space and the existence of a state of absolute rest. Clarke, a Newtonian, held that there was an objective truth to one's position in space, Leibniz denied this, arguing that the entire universe could shift by some distance and not even God could know the difference. The two positions would come to be called substantivalism and relationalism, and the debate would see a tremendous revival in the philosophical and scientific communities after Einstein's development of the theory of relativity. (McDonough, 2014).

Notes: Rebound in 20th century leather, text block with some minor chips and discoloration throughout.

1874? Theodore Lyman III

Manuscript on the philosophic foundations of atomic theory.

Theodore Lyman III was a natural scientist, military officer in the American Civil War, congressman and father to Theodore Lyman IV, who discovered the Lyman Series of atomic spectral lines. This manuscript, written at approximately the time that Lyman IV was born, is a short criticism of 19th century atomic theory. Lyman III argues here, albeit briefly, that it is untenable for physical matter to be indivisible at some scale.

Notes: Two leaves (three written pages) tipped into a copy of Fernand Papillon's *La Nature et la Vie*, Paris: Didier et Cie, 1874. Manuscript written in English with Lyman's signature on both the manusciprt and the book's front free endpaper. The bottom of the second leaf of the manuscript is folded up from below the book's textblock and a small tear appears near the spine at the crease. The text is largely legible, though there are some words which are faded or rubbed.

1935 Ronald Aylmer Fisher

The Design of Experiments
Edinburgh: Oliver & Boyd.

Fisher's Design of Experiments marks one of the most significant advances in experimental science in twentieth century. Here Fisher outlines treating the possibility that a hypothesis is incorrect as itself a hypothesis, called the *null hypothesis. (*Romeijn, 2017). This concept is now standard in experimental analysis.

Although Fisher was already a well-known statistician at the time, this book is exceedingly rare, with only one other copy having appeared on the market since at least 2015.

Notes: This book's condition is somewhat strange. The binding is very tight and the text clear with no foxing or other marks, and the boards and corners are crisp. However, many pages show a symmetrical discoloration, as if someone had kept newsclippings pressed between the pages. (What is strange is that the prevalence of these discolorations would normally be accompanied by stress to the binding, whereas this binding appears as if the book has never been read.)

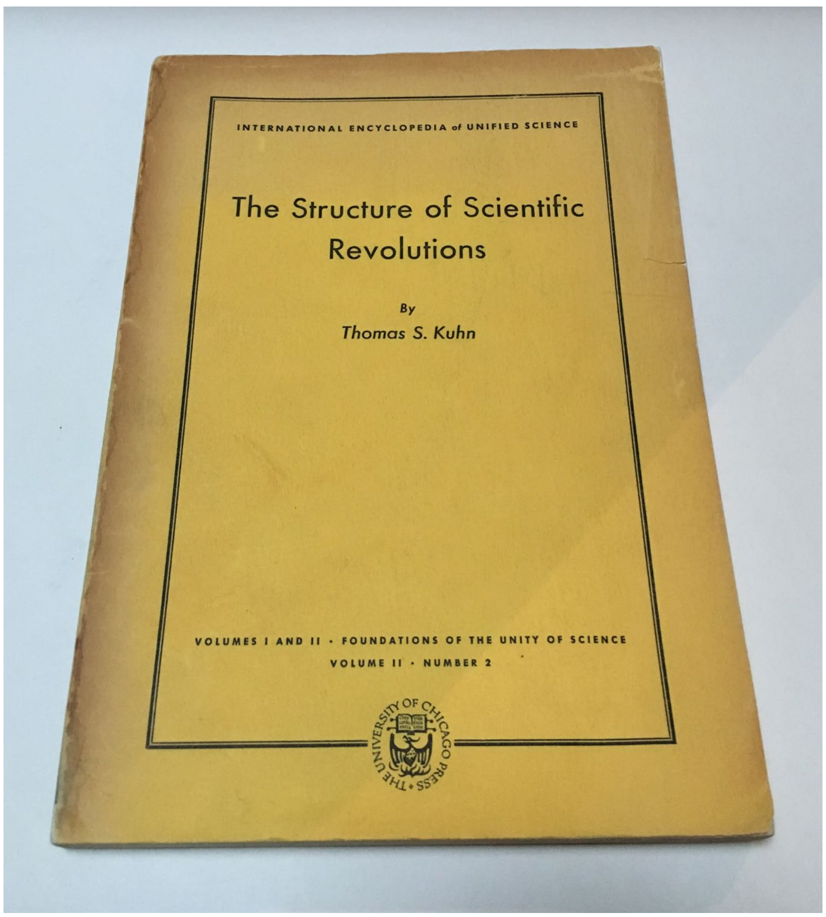
1962 Thomas Samuel Kuhn

The Structure of Scientific Revolutions
International Encyclopedia of Unified Science
Foundations of the Unity of Science, 2(2). University of Chicago Press.

This monograph is one of the most influential philosophy of science books of the twentieth century. Here Kuhn explains how science can encounter 'crises' that force a paradigm shifts in the scientific community, ultimately resulting in a scientific revolution. (Bird, 2018).

This edition preceded the first commercial release of the book by the University of Chicago Press in the same year.

Notes: Bound in paper wrappers (as issued) with slight discoloration near the spine. There is some bumping at the corners and a small crease near the top of the front wrapper (see photo), but otherwise in very good to near fine condition.



Kuhn, 1962.

Wish List

The following are but a few items that appear in my ideal collection. They are listed here in chronological order

1. Max Planck. (1900). Zur Theorie des Gesetzes der Energieverteilung im Normalspectrum (Theory of the Law of Energy Distribution in the Normal Spectrum). *Verhandlungen der Deutschen Physikalischen Gesellschaft, 2*.
-This is Planck's first introduction of 'his' constant (the first 'quantized' theory) in response to the problems that arose in early theories of radiation.

2. Albert Einstein. 1905-1916. Multiple papers in *Annalen der Physik* (various volumes).
- Einstein published a tremendous number of very important foundational papers between 1905 and 1916. These include his publications of the special and general theories of relativity, as well as papers outlining his theory of photons, the photoelectric effect, and Brownian motion. Almost all were published in *Annalen der Physik*. These papers frequently appear on the market, and so are not tremendously difficult to find, but are typically rather expensive.

3. Paul Langevin et Maurice de Broglie, (eds.). (1912) *La Théorie du Rayonnement et les Quanta. Rapports et Discussions de la Réunion tenue à Bruxelles, du 30 octobré au 3 Novembre 1911 sous les Auspices de M.E. Solvay. [The Theory of Radiation and the Quanta. Proceedings and discussions from the meeting held at Brussels from October 30 to November 3, 1911 with the support of M.E. Solvay]* Paris: Gauthier-Villars.
- In 1911, some of the prominent physicists of the time met to discuss and debate the meaning of Planck's constant. This meeting was recorded and published in this rare volume. (As a side note, I am currently preparing to apply for a post-doctorol fellowship that will involve translating these proceedings into English.)

4. Emmy Noether. (1918). Invariante Variationsprobleme. [Invariant Variation Problems, or Invariant Quantities and the Calculus of Variations.] *Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-Physikalische Klasse*.
- Noether's theorem, published here, proves that every spacetime symmetry is associated with a conservation law. For example, translational symmetry produces the conservation of momentum. This foundational theorem is of particular interest to my reserach.

5. Werner Heisenberg, Max Born and Pasqual Jordan. (1925). Zur Quantenmechanik. [On Quantum Mechanics] I and II. *Zeitschrift für Physik, 34* and *35.*
- These papers present the first complete formalization of contemporary quantum mechanics.

6. Paul Langevin et Maurice de Broglie, (eds.). (1927). *Électrons et Photons. Rapports et Discussions du Cinquieme Conseil de Physique tenu a Bruxelles du 24 au 29 Octobre 1927 sous les Auspices de L'Institut International de Physique de Solvay. [Electrons and Photons. Proceedings and discussions from the fifth conference on physics held at Brussels from October 24 to 29, 1927 with the support of the Solvay International Physics Institute.]* Paris: Gauthier-Villars.
- The fifth Solvay conference famously saw a heated debate between Einstein and Bohr. The argument would last for years, perhaps most famously expressed in their 1935 papers below.

7. Albert Einstein, Boris Podolsky and Nathan Rosen. (1935). Can Quantum-Mechanical Description of Physical Reality be Considered Complete? *Physical review, 47*(10).
8. Neils Bohr. (1935). Can quantum-mechanical description of physical reality be considered complete? *Physical review, 48*(8).
- These two papers, published with the same title in the same year of the *Physical Review*, outline the Einstein-Podolsky-Rosen "paradox" (their argument for hidden variables) and Bohr's response. Both papers are standard reading in philosophy of quantum mechanics.

9. Grete Hermann. (1935). Die naturphilosophischen Grundlagen der Quantenmechanik. [The Philosophical Foundations of Quantum Mechanics.] *Naturwissenschaften, 23*(42).
- Hermann, a mathematician and philosopher, has recently been discussed by Crull and Baggiagaluppi (2016) as an underappreciated woman in the philosophy of physics. This paper, perhaps her most well-known, represents a philosophical analysis of the theoretical foundations of quantum mechanics.

10. John Bell. (1964). On the Einstein-Podolsky-Rosen Paradox. *Physics Physique Fizika, 1*(3).
- The first publication of Bell's theorem, which would ultimately disprove the possibility of Einstein-Podolsly-Rosen-type hidden variables theories. The journal was not well circulated and was dismantled after less than four years, making this paper exceeding rare.

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