The Quantum Underground
Early Quantum Theory Textbooks

Clayton Gearhart
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(Minnesota)

American Physical Society

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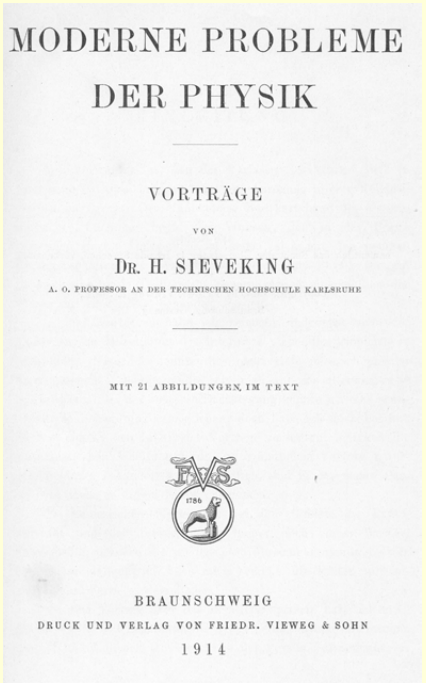
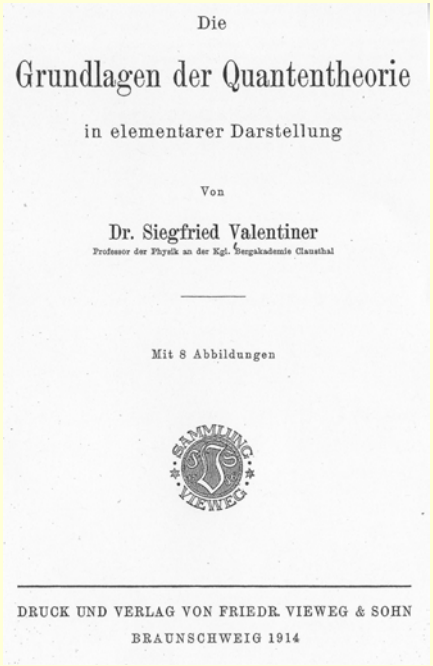
in cooperation with the quantum textbook project, sponsored by the Max Planck Institute for the History of Science, Berlin.


MODERNE PROBLEME
DER PHYSIK

VORTRÄGE
VON
DR. H. SIEVEKING
A. O. PROFESSOR AN DER TECHNISCHEN HOCHSCHULE KARLSRUHE

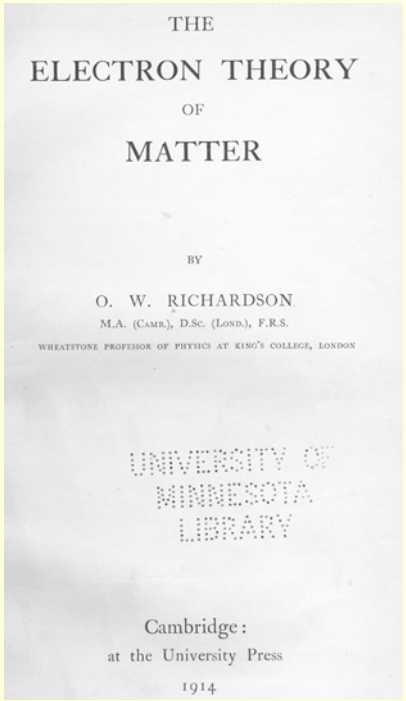
MIT 21 ABBILDUNGEN IM TEXT

BRAUNSCHWEIG
DRUCK UND VERLAG VON FRIEDR. VIEWEG & SOHN
1914


Die
Grundlagen der Quantentheorie
in elementarer Darstellung
Von
Dr. Siegfried Valentiner
Professor der Physik an der Kgl. Bergakademie Clausthal

Mit 8 Abbildungen

DRUCK UND VERLAG VON FRIEDR. VIEWEG & SOHN
BRAUNSCHWEIG 1914


THE
ELECTRON THEORY
OF
MATTER
BY
O. W. RICHARDSON
M.A. (CAMB.), D.SC. (LOND.), F.R.S.
WHEATSTONE PROFESSOR OF PHYSICS AT KING'S COLLEGE, LONDON

Cambridge:
at the University Press
1914

Fritz Reiche's 1921 quantum theory book

Die Quantentheorie

Ihr Ursprung und ihre Entwicklung

Von

Fritz Reiche

Mit 15 Textfiguren

Berlin
Verlag von Julius Springer
1921

THE
QUANTUM THEORY

BY

FRITZ REICHE

PROFESSOR OF PHYSICS IN THE UNIVERSITY OF BRESLAU

TRANSLATED BY H. S. HATFIELD, B.Sc., Ph.D., AND
HENRY L. BROSE, M.A.

WITH FIFTEEN DIAGRAMS

SECOND EDITION

METHUEN & CO. LTD.
36 ESSEX STREET W.C.
LONDON

Fritz Reiche (1883–1969)

Fritz Reiche was one of the very few research pupils of Max Planck ... He was a tiny delicate Jew who combined the typical humor of the Berliner with a deep melancholy and pessimism. ... I learned from him a great deal about radiation and quantum theory which he had studied at the source, in personal contact with Planck.

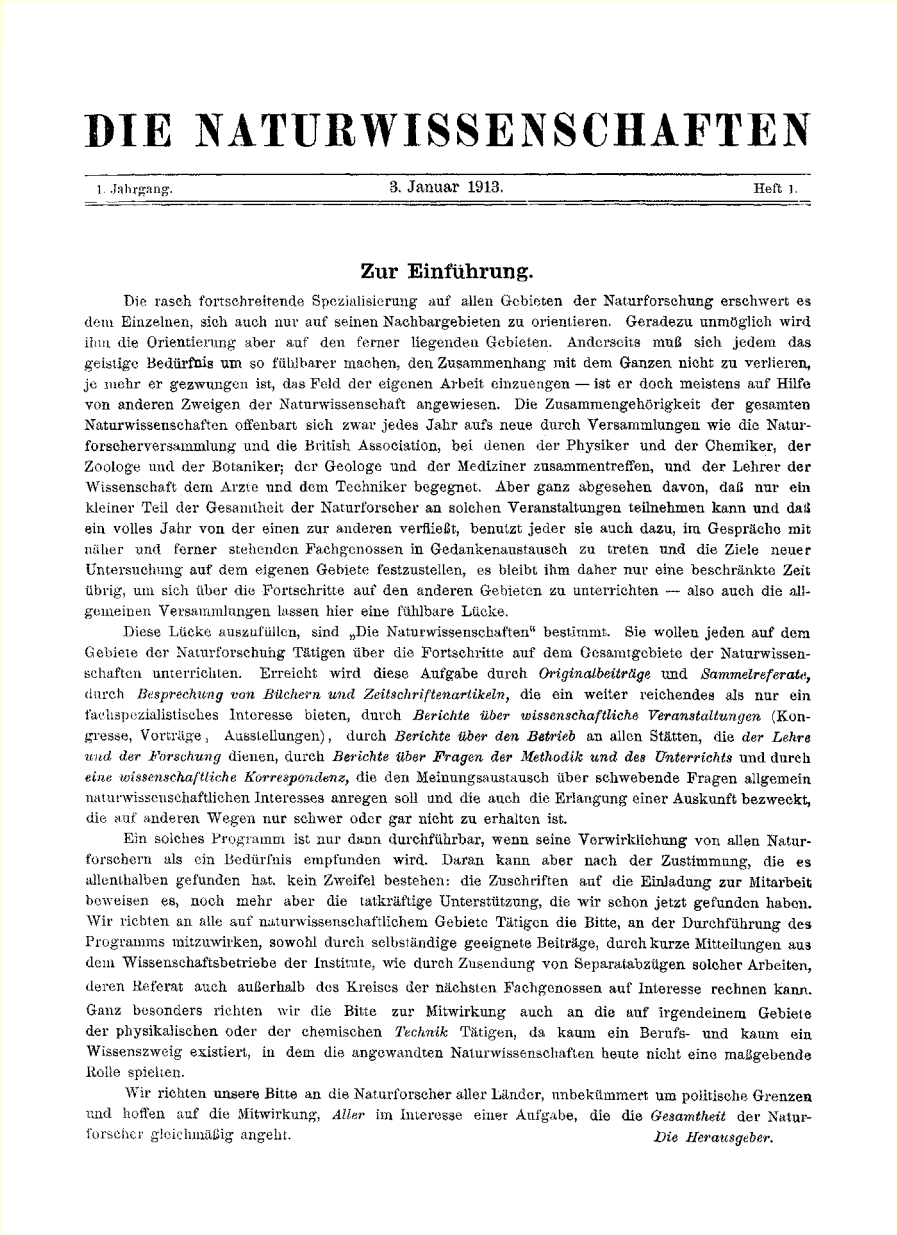
–Max Born

- Ph.D. with Planck, 1907
- 1908–11: in Breslau, learning experimental physics with Otto Lummer
- 1913: Instructor (*Privatdozent*) at the University of Berlin
- 1915–18: assistant to Planck
- 1919–1920: advisor to Fritz Haber's Physical Chemistry Institute in Berlin; "little oracle"
- 1921–1933: Professor in Breslau
- 1921: publication of *Die Quantentheorie*

From late teens through mid 1920s, Reiche published a series of influential papers on quantum theory, on such topics as

- dispersion
- spectrum of helium
- rotational specific heat of hydrogen

1913: Die Naturwissenschaften



DIE NATURWISSENSCHAFTEN

1. Jahrgang. 3. Januar 1913. Heft 1.

Zur Einführung.

Die rasch fortschreitende Spezialisierung auf allen Gebieten der Naturforschung erschwert es dem Einzelnen, sich auch nur auf seinen Nachbargebieten zu orientieren. Geradezu unmöglich wird ihm die Orientierung aber auf den ferner liegenden Gebieten. Anderseits muß sich jedem das geistige Bedürfnis um so fühlbarer machen, den Zusammenhang mit dem Ganzen nicht zu verlieren, je mehr er gezwungen ist, das Feld der eigenen Arbeit einzuengen — ist er doch meistens auf Hilfe von anderen Zweigen der Naturwissenschaft angewiesen. Die Zusammengehörigkeit der gesamten Naturwissenschaften offenbart sich zwar jedes Jahr aufs neue durch Versammlungen wie die Naturforscherversammlung und die British Association, bei denen der Physiker und der Chemiker, der Zoologe und der Botaniker, der Geologe und der Mediziner zusammentreffen, und der Lehrer der Wissenschaft dem Arzte und dem Techniker begegnet. Aber ganz abgesehen davon, daß nur ein kleiner Teil der Gesamtheit der Naturforscher an solchen Veranstaltungen teilnehmen kann und daß ein volles Jahr von der einen zur anderen verfließt, benutzt jeder sie auch dazu, im Gespräche mit näher und ferner stehenden Fachgenossen in Gedankenaustausch zu treten und die Ziele neuer Untersuchung auf dem eigenen Gebiete festzustellen, es bleibt ihm daher nur eine beschränkte Zeit übrig, um sich über die Fortschritte auf den anderen Gebieten zu unterrichten — also auch die allgemeinen Versammlungen lassen hier eine fühlbare Lücke.

Diese Lücke auszufüllen, sind „Die Naturwissenschaften" bestimmt. Sie wollen jeden auf dem Gebiete der Naturforschung Tätigen über die Fortschritte auf dem Gesamtgebiete der Naturwissenschaften unterrichten. Erreicht wird diese Aufgabe durch *Originalbeiträge* und *Sammelreferate*, durch *Besprechung von Büchern und Zeitschriftenartikeln*, die ein weiter reichendes als nur ein fachspezialistisches Interesse bieten, durch *Berichte über wissenschaftliche Veranstaltungen* (Kongresse, Vorträge, Ausstellungen), durch *Berichte über den Betrieb* an allen Stätten, die *der Lehre und der Forschung* dienen, durch *Berichte über Fragen der Methodik und des Unterrichts* und durch *eine wissenschaftliche Korrespondenz*, die den Meinungsaustausch über schwebende Fragen allgemein naturwissenschaftlichen Interesses anregen soll und die auch die Erlangung einer Auskunft bezweckt, die auf anderen Wegen nur schwer oder gar nicht zu erhalten ist.

Ein solches Programm ist nur dann durchführbar, wenn seine Verwirklichung von allen Naturforschern als ein Bedürfnis empfunden wird. Daran kann aber nach der Zustimmung, die es allenthalben gefunden hat, kein Zweifel bestehen: die Zuschriften auf die Einladung zur Mitarbeit beweisen es, noch mehr aber die tatkräftige Unterstützung, die wir schon jetzt gefunden haben. Wir richten an alle auf naturwissenschaftlichem Gebiete Tätigen die Bitte, an der Durchführung des Programms mitzuwirken, sowohl durch selbständige geeignete Beiträge, durch kurze Mitteilungen aus dem Wissenschaftsbetriebe der Institute, wie durch Zusendung von Separatabzügen solcher Arbeiten, deren Referat auch außerhalb des Kreises der nächsten Fachgenossen auf Interesse rechnen kann. Ganz besonders richten wir die Bitte zur Mitwirkung auch an die auf irgendeinem Gebiete der physikalischen oder der chemischen *Technik* Tätigen, da kaum ein Berufs- und kaum ein Wissenszweig existiert, in dem die angewandten Naturwissenschaften heute nicht eine maßgebende Rolle spielen.

Wir richten unsere Bitte an die Naturforscher aller Länder, unbekümmert um politische Grenzen und hoffen auf die Mitwirkung, *Aller* im Interesse einer Aufgabe, die die *Gesamtheit* der Naturforscher gleichmäßig angeht.

Die Herausgeber.

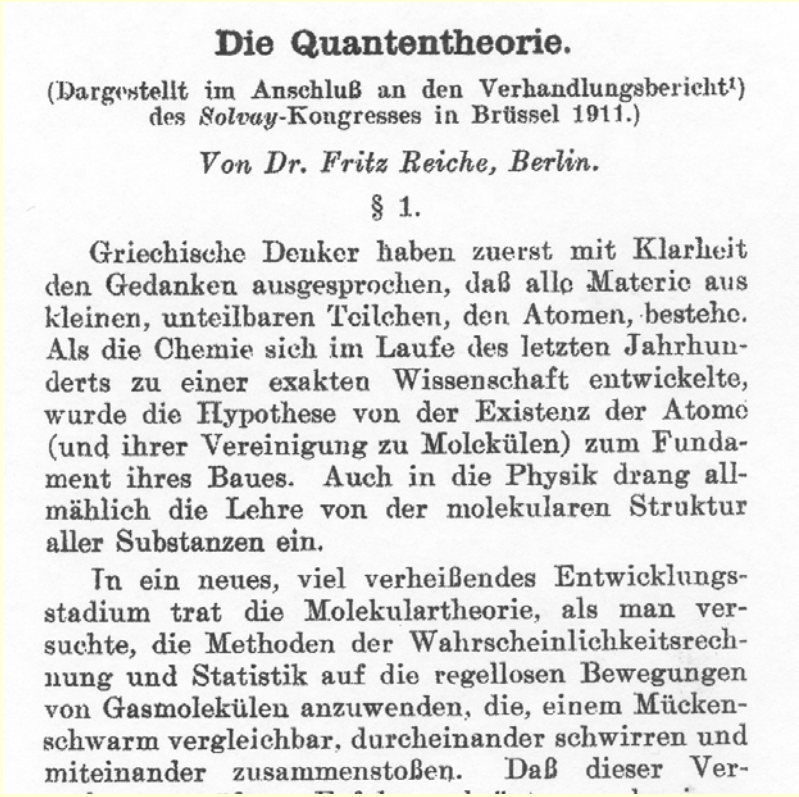
In 1913, Arnold Berliner persuaded Ferdinand Springer to establish a new journal, *Die Naturwissenschaften*, which like *Nature in Britain* and *Science* in the United States, would report on new developments in all of the natural sciences to all scientists.

The rapidly progressing specialization in all branches of research in the natural sciences [*Naturforschung*] makes it difficult for the individual to become informed about even neighboring domains. It is almost impossible for him to become acquainted with more distant ones.

"Die Naturwissenschaften" is determined to fill this gap.

See Michael Stöltzner, Ph.D. dissertation (2003)

Fritz Reiche, *Die Naturwissenschaften*, and Quantum Theory: 1913



Die Quantentheorie.

(Dargestellt im Anschluß an den Verhandlungsbericht[1]) des *Solvay*-Kongresses in Brüssel 1911.)

Von Dr. Fritz Reiche, Berlin.

§ 1.

Griechische Denker haben zuerst mit Klarheit den Gedanken ausgesprochen, daß alle Materie aus kleinen, unteilbaren Teilchen, den Atomen, bestehe. Als die Chemie sich im Laufe des letzten Jahrhunderts zu einer exakten Wissenschaft entwickelte, wurde die Hypothese von der Existenz der Atome (und ihrer Vereinigung zu Molekülen) zum Fundament ihres Baues. Auch in die Physik drang allmählich die Lehre von der molekularen Struktur aller Substanzen ein.

In ein neues, viel verheißendes Entwicklungsstadium trat die Molekulartheorie, als man versuchte, die Methoden der Wahrscheinlichkeitsrechnung und Statistik auf die regellosen Bewegungen von Gasmolekülen anzuwenden, die, einem Mückenschwarm vergleichbar, durcheinander schwirren und miteinander zusammenstoßen. Daß dieser Ver-

In June 1913, Reiche published a nine page, two part article on quantum theory, intended to summarize the 1911 Solvay conference. It was not the first article on quantum theory to appear in *Die Naturwissenschaften*. But it was by far the most comprehensive. Reiche began:

Greek thinkers were the first to state clearly that all matter consists of small, indivisible particles, atoms.

He discussed 19th century kinetic theory, Brownian motion, electron theory, and black-body radiation; and went on from there to give a thorough description of the experimental evidence for and theoretical scope of quantum theory in 1913, in clear, striking, non-technical language.

Reiche concluded by quoting Marcel Brillouin at the first Solvay Conference:

It has become necessary to introduce a discontinuity into our physical ideas, an element that can change only in jumps, whose existence we had not suspected until a few years ago.

Lessons

By 1913,

- Quantum theory was sufficiently established to merit several articles for non-specialist readers in *Die Naturwissenschaften*, including a May article by Max Born on black body theory.
- Although another four years would pass before Reiche began to publish in quantum theory, it is evident that in 1913 he had an encyclopedic knowledge of the subject.
- Finally, Reiche wrote clear, striking prose, and showed that he could present what even by 1913 was a complex, many-faceted subject to scientists at an introductory level.

Book reviews in *Die Naturwissenschaften*

Between 1913 and 1936, Reiche published some 20 book reviews in *Die Naturwissenschaften*, the majority in the teens and early 20s, and many of them on quantum theory: for example

- Arnold Eucken's translation of the proceedings of the 1911 Solvay conference :

  The actual significance, the foundations of this theory are still deeply obscure.

- Planck's (1908) and Wien's (1913) lectures at Columbia University.
- Planck's 1920 Nobel Prize lecture:

  Max Planck gives ... an overview of the new wonderland that he opened up twenty years ago.

- Books by Hermann Sieveking (1914), Siegfried Valentiner (1914, 1919), Arthur March (1919), Ludwik Silberstein (1920), and Rudolf Ladenburg (1921).

The Quantum Underground

1912–1914

Publication of four books that treated quantum theory, by

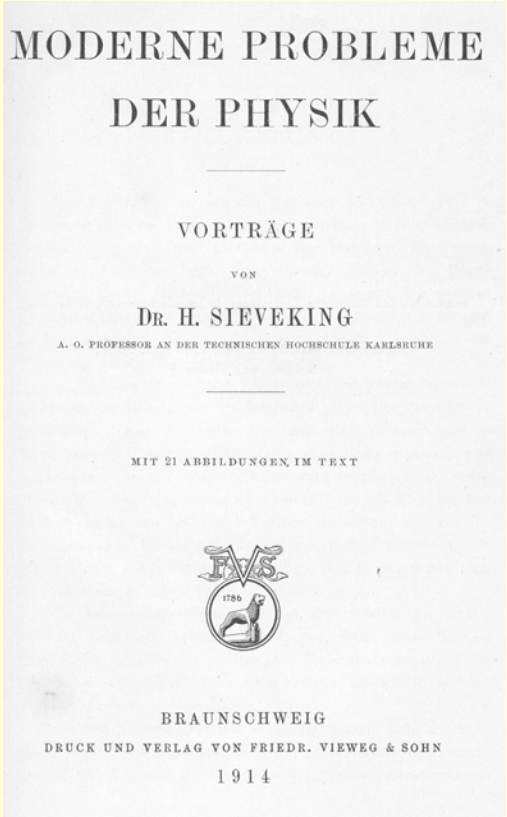
- Hermann Sieveking (1875–1914)
- Siegfried Valentiner (1876–1971)
- Owen Richardson (1879–1959) (not reviewed by Reiche)

All three authors were experimental physicists.

None of the three specialized in quantum theory.

All three gave sophisticated, well informed accounts!

Hermann Sieveking (1875–1914)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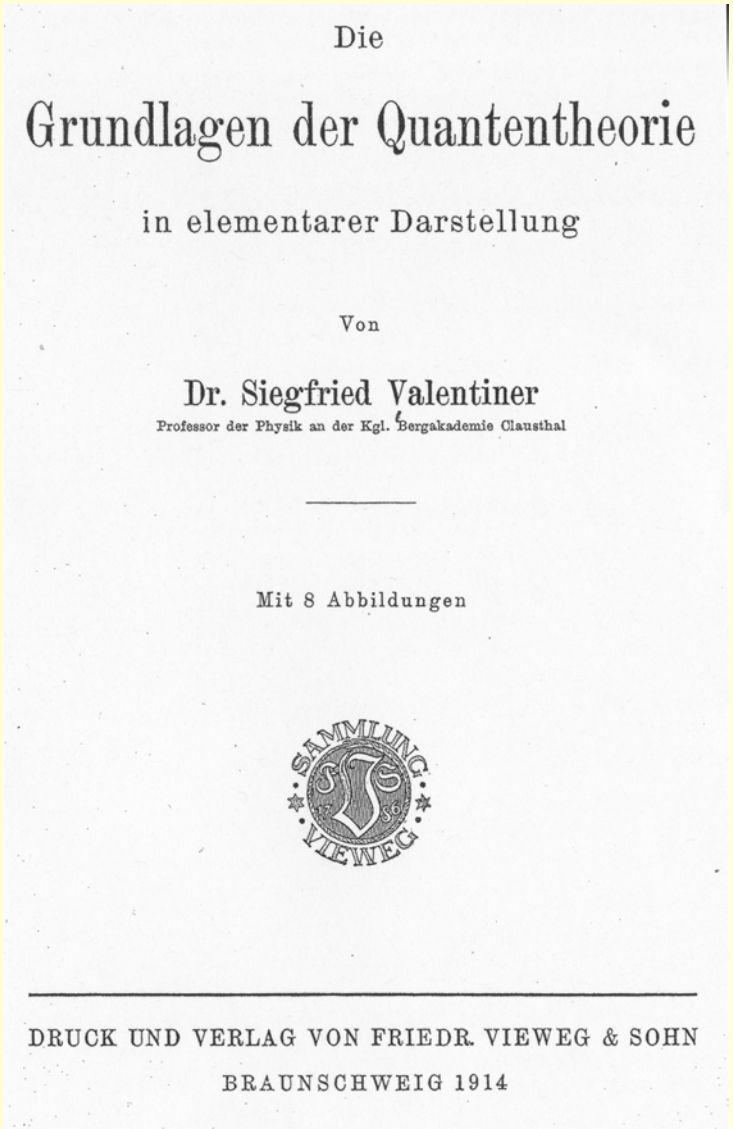
BRAUNSCHWEIG
DRUCK UND VERLAG VON FRIEDR. VIEWEG & SOHN
1914

- Ph.D. 1899 (Freiburg)
- ausserordentlicher Professor, Karlsruhe Technical University
- research (divided between experiment, theory) on such topics as radioactivity and electrical discharge in gases. He was also interested in airships, on which he lectured at Karlsruhe in 1913.
- had several articles in *Die Naturwissenschaften,* which published a 1½ page obituary
- book was based on lectures, in winter 1913, to the local chapter of the Association of German Chemists who, he tells us in the introduction, wanted to learn about "**recent achievements in theoretical chemistry and physics.**"

- topics: electron theory, radioactivity, x-rays, relativity, and a final, thirty-page chapter on "Progress in Thermodynamics" — quantum theory (black-body radiation, Planck's two theories, Einstein's light quanta, Nernst's heat theorem, specific heats of solids)

This last chapter had appeared earlier in the Proceedings of the Karlsruhe Natural Sciences Society, dated December 1912, where Sieveking tells us that it had been written even earlier for a prize on the theme "Description of quantum theory," sponsored by the Eisenlohr Foundation.

Siegfried Valentiner (1876–1971)



Die

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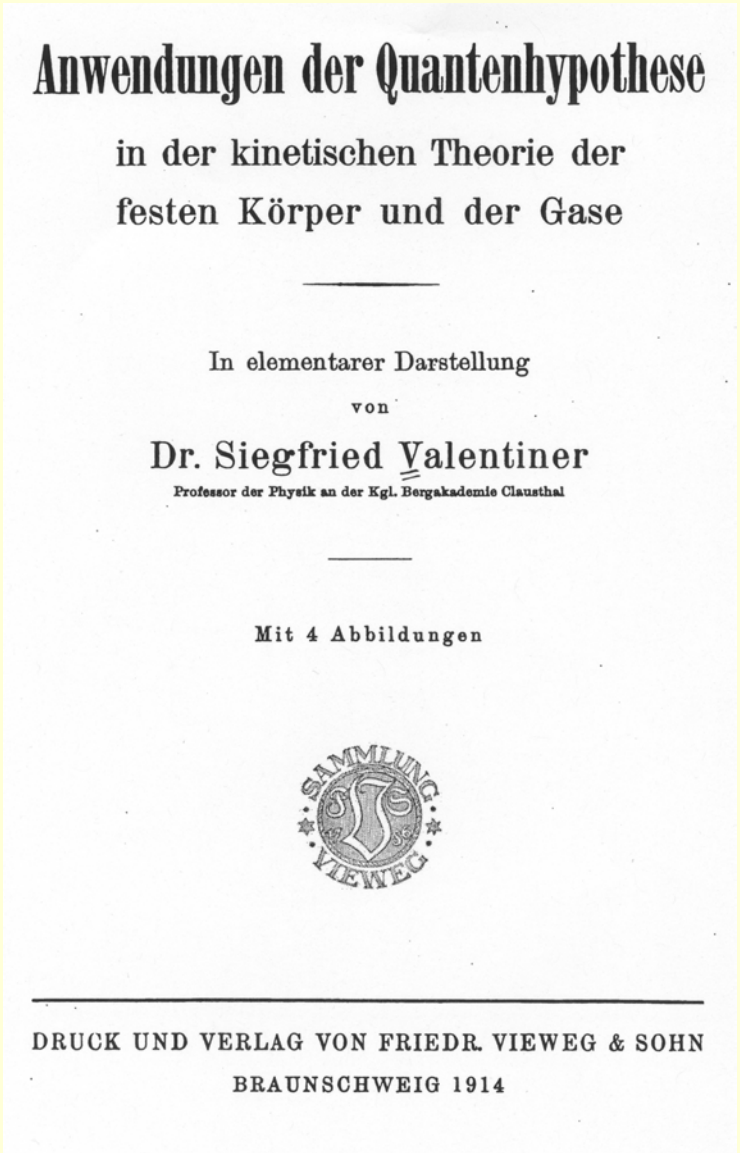
SAMMLUNG VIEWEG

DRUCK UND VERLAG VON FRIEDR. VIEWEG & SOHN

BRAUNSCHWEIG 1914

67 pages



Anwendungen der Quantenhypothese

in der kinetischen Theorie der festen Körper und der Gase

In elementarer Darstellung

von

Dr. Siegfried Valentiner

Professor der Physik an der Kgl. Bergakademie Clausthal

Mit 4 Abbildungen

SAMMLUNG VIEWEG

DRUCK UND VERLAG VON FRIEDR. VIEWEG & SOHN

BRAUNSCHWEIG 1914

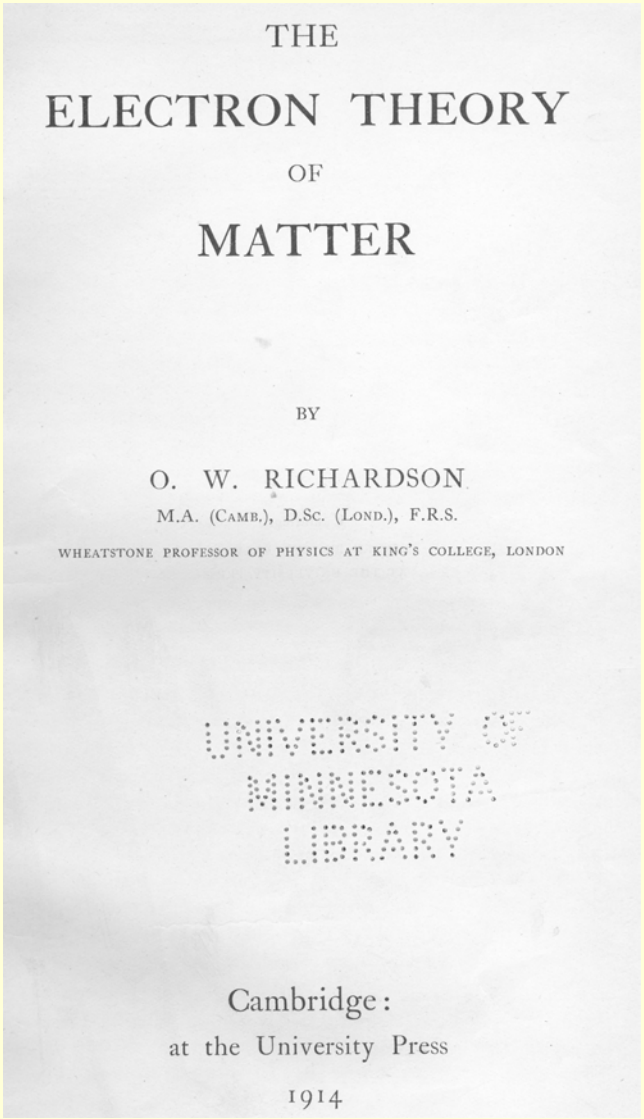
72 pages

Siegfried Valentiner (1876–1971)

- Ph.D. 1900 (Heidelberg)
- at Physikalisch-Technische Reichsanstalt in Berlin: 1903 paper comparing optical temperature scales with nitrogen gas thermometers
- 1906: published textbook on vector analysis (remained in print through 1960s)
- 1910: Professor at School of Mines [*Bergacademie*], Clausthal
- several articles in *Die Naturwissenschaften* (1915–1964)

- explicitly intended for beginning students
- comprehensive coverage: Blackbody radiation, light quanta, Planck's two theories, specific heats of solids, Sommerfeld's theory of non-periodic processes (x-rays, photoelectric effect), rotational specific heats, molecular spectra, prospects for quantizing monatomic gases (Sackur-Tetrode)
- apparently sold well; plenty of inexpensive copies are currently available on the used book market

Owen Richardson (1879–1959)


THE

ELECTRON THEORY

OF

MATTER

BY

O. W. RICHARDSON

M.A. (Camb.), D.Sc. (Lond.), F.R.S.

WHEATSTONE PROFESSOR OF PHYSICS AT KING'S COLLEGE, LONDON

Cambridge:

at the University Press

1914

Richardson won the Nobel Prize in 1928 for his work on thermionic emission.

- written for graduate course at Princeton
- much less systematic treatment compared to Sieveking and Valentiner: blackbody radiation, brief discussion of specific heats of solids
- hoped that **the difficulties which beset the electron theory of metallic conduction … may be overcome by the application of the ideas underlying Planck's theory of radiation.**
- He also gave what is probably the first textbook treatment of Bohr's theory!

See Ole Knudsen, "O. W. Richardson and the Electron Theory of Matter, 1901–1906" in Buchwald and Warwick, eds., *History of the Electron*

The Quantum Underground

Common Themes

- All three are skeptical of Einstein's light quantum hypothesis
- All three show a marked preference for Planck's "second theory"
- All three emphasize the importance of the photoelectric effect, and all three promote quantum (albeit not light quantum) explanations
- All three cite Walther Nernst's February 1911 *Zeitschrift für Electrochemie* paper, "**On the theory of specific heats and the lessons of energy quanta for questions in physical chemistry generally.**"

Nernst's paper seems to have been important in introducing quantum theory to the wider community of physicists and physical chemists. Sieveking and Valentiner rely heavily on it.

The Quantum Underground

As Nernst was planning the first Solvay conference, Planck wrote him in June, 1910, to say that he thought the conference was premature, and that many potential participants did not yet realize the challenge that quantum theory presented to physics.

The evidence presented here suggests that Planck was overly pessimistic:

By 1912–1914:

- articles/reviews in *Die Naturwissenschaften*
- Karlsruhe prize competition (!)
- books by Sieveking, Valentiner, Richardson

Quantum theory was no longer confined to the experts!

In the time remaining, I will say a little about Fritz Reiche's 1921 textbook.

The Quantum Theory
Fritz Reiche
1921

The book appeared in 1921, published by Springer; English translation in 1922.

The book appears to have sold well:

- Inexpensive used copies are still widely available.
- The English translation went through three printings, the last in 1930.

1. Very few topics in quantum theory went unmentioned.

- On unsettled questions (light quantum; Planck's first or second theory), Reiche usually gave a careful summary, but refrained from taking sides.

2. Level was introductory:

- main text was about 160 pages (125 pages in English translation)
- about 50 pages of end notes, many of them extending and deepening the treatment in the text
- historically accurate! Even today, one can get a good picture of quantum theory around 1920 from Reiche's book.

3. As in his *Naturwissenschaften* pieces, Reiche's writing was clear and forceful.

"Astonishing Successes," "Bitter Disappoiintment"

This conclusion [Planck's quanta] is a slap in the face to classical electrodynamics….

(This striking phrase, which first appeared in 1913, did not survive translation into English!)

If we now survey the whole structure, ... we cannot avoid a feeling of admiration ... for the astonishing successes that have sprung from the quantum theory.

Nonetheless, no one who studies the quantum theory will be spared bitter disappointment. ... In spite of a comprehensive formulation of quantum rules, we have not come one step nearer to understanding the heart of the matter.

The decision has not yet been made, as to whether, as Planck's first theory requires, only quantum-allowed states exist..., or whether, according to Planck's second version, intermediate states are also possible. We are still completely in the dark about the details of the absorption and emission process.... Is radiation really propagated in the manner claimed by classical wave theory, or does it also have a quantum character?

Over all these problems there hovers at the present time a mysterious obscurity.

from Reiche's conclusion

Fritz Reiche as teacher

In 1949 I was completing course work for a Ph.D. degree at New York University (NYU) but needed one additional course in statistical mechanics as a degree requirement. The course was given by a diminutive professor with a slight German accent whose name was Fritz Reiche. This course turned out to be the most memorable one I was ever to take at NYU…. The clarity, the seeming simplicity of the concepts ... succeeded in transmitting to the listener the impression that he or she was able to follow deeply and with brilliant clarity the true essence of statistical mechanics.

When reading Reiche's book I discovered, not to my surprise, that it had precisely the same flavor that I recalled from Reiche's lectures at NYU. ... It remains one of the most accessible, and substantive textbooks I have ever read.

Benjamin Bederson (*Physics in Perspective,* 2005)

Reiche came to the United States in 1941, and spent most of the rest of his career at New York University. His papers are on file at the Niels Bohr Library, in College Park, Maryland. There I came across a handwritten manuscript of a modern physics text that seems to date from the mid-1930s (judging from the material on nuclear physics), when Reiche was back in Berlin after being dismissed from his professorship in Breslau. It was a sad document to read. Reiche must have known that it could never have been published in Germany. It serves to remind us, as we study the exciting days of early quantum theory, that our actors were players on a wider stage. It is a side of this history that we do well to keep in mind.