# *Catalogue 77:*

# *20th Century Physics*

## *From the Libraries of Henri Becquerel, Owen Chamberlain, Walther Gerlach, Pascual Jordan, H. A. Kramers, Bruno Rossi, Emilio Segrè, Arnold Sommerfeld & Gregor Wentzel*

Catalogued by Diana H. Hook

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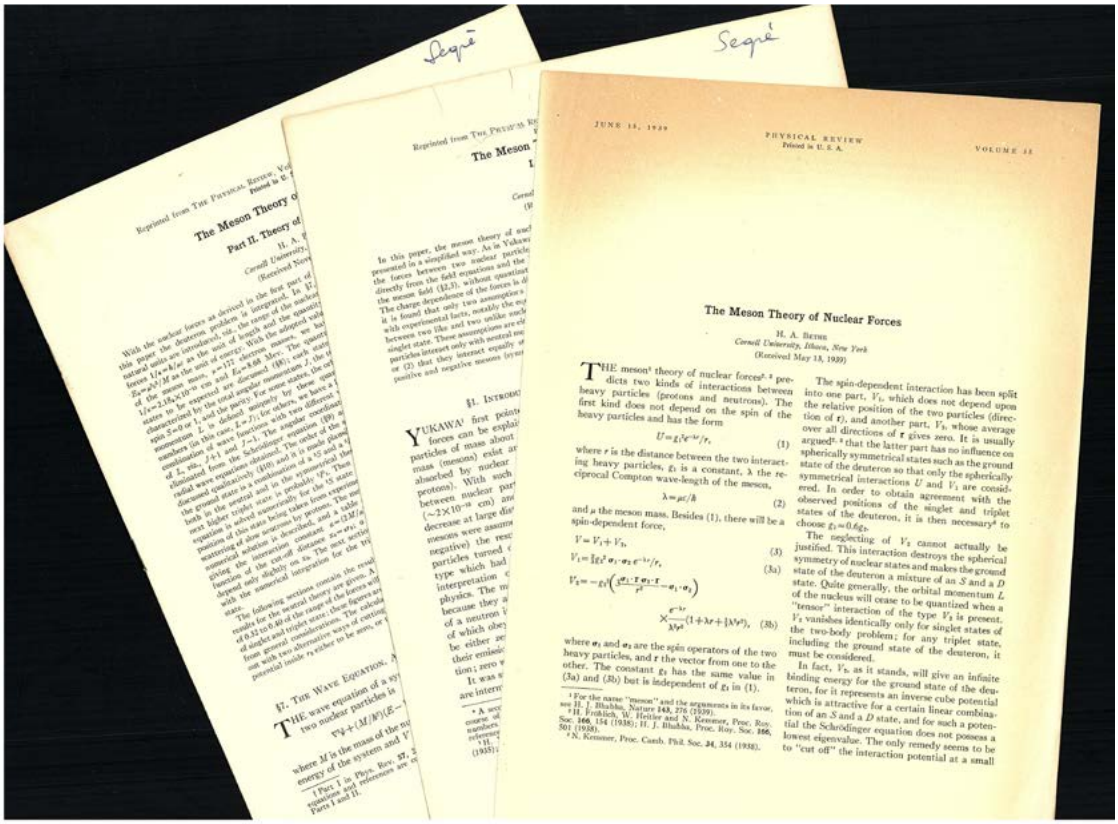



**1. Bethe, Hans** (1906-2005). (1) The meson theory of nuclear forces. Offprint from *Physical Review* 55 (1939). 1261-1263pp. Without wrappers as issued. (2) The meson theory of nuclear forces. I: General theory. Offprint from *Physical Review* 57 (1940). 260-272pp. Without wrappers as issued. (3) The meson theory of nuclear forces. Part II: Theory of the deuteron. Offprint from *Physical Review* 57 (1940). 390-413pp. Without wrappers as issued. Together 3 items. 268 x 201 mm. Some toning, especially in no. (1), first and second leaves of no. (2) torn affecting a few words in the running heads, otherwise very good. From the library of Nobel laureate Emilio Segrè (1905-89), with his signature on the first pages of nos. (2) and (3). $1250

**First Editions, Offprint Issues.** Hans Bethe, one of the greatest physicists of the twentieth century, pioneered the application of quantum mechanics to atomic, solid-state and (particularly) nuclear physics. "Bethe was unrivalled in his comprehensive mastery of nuclear phenomena, experimental data and descriptive models . . .by applying the emerging phenomenology Bethe achieved remarkable successes that ranged from understanding the energy production in stars to guiding the harnessing of nuclear fission as part of the Manhattan Project" (Negele, p. 165). He received the Nobel Prize in 1967 for his work in the theory of stellar nucleosynthesis.

The above three papers discuss the meson theory of nuclear forces, introduced by Yukawa in 1935, which posited that the enormous force binding protons and neutrons together in the atomic nucleus was caused by the exchange of particles known as mesons (now called pions). "As his starting point for nuclear physics, Hans [Bethe] chose the nuclear force, whose long-range behavior was given uniquely by a one-pion exchange potential. Before the war, Hans had worked out, in his own characteristic physical way, the spin-dependent part of that long-range potential, and he used it with an appropriate cutoff to calculate the properties of the deuteron" (Negele, p. 167). Negele, "Hans Bethe and the theory of nuclear matter," in *Hans Bethe and His Physics,* ed. G. Brown and C.-H. Lee, pp. 165-173.

These papers are from the library of Nobel Laureate Emilio Segrè, discoverer of the antiproton and the elements technetium and astatine. 37776

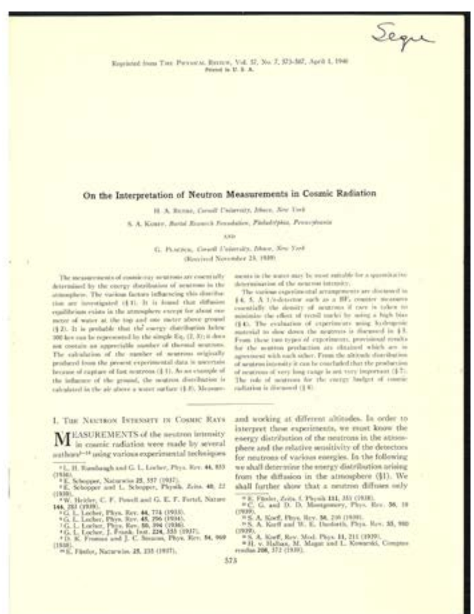
**2. [Bethe, Hans** (1906-2005).] **Rose, Morris E.** (1911-67) and **Bethe.** On the absence of polarization in electron scattering. Offprint from *Physical Review* 55 (1939). 277-289pp. 269 x 201 mm. Without wrappers as issued. Light creasing but very good. $500

**First Edition, Offprint Issue.** In 1932 British physicist Nevill Mott published his quantitative theory of the polarization of electrons by double scattering, based on Dirac's theory of the electron. Experimental results failed to agree with Mott's theory, however, as reported in several subsequent papers, including this one by Rose and Bethe. "They tried various ways of solving the problem and concluded as follows: 'In addition to multiple scattering we have investigated the depolarization effect of other processes . . . The result of these considerations may be stated very briefly. Unfortunately, none of the effects considered produces any appreciable depolarization of the electrons and the discrepancy between theory and experiment remains—perhaps more glaring than before'" (A. Franklin, *The Neglect of Experiment,* p. 67). 51024

**3. Bethe, Hans** (1906-2005); **Fred Hoyle** (1915-2001); and **Rudolf Peierls** (1907-95). Interpretation of beta-disintegration data. Offprint from *Nature* 143 (1939). [3]pp. 216 x 141 mm. Bifolium; without wrappers as issued. Some light creasing but very good. $1500

**First Edition, Offprint Issue.** The true author of the present paper was British astrophysicist Fred Hoyle, famous for his theory of the creation (nucleosynthesis) of chemical elements by nuclear fusion within stars. In the late 1930s Hoyle, then a graduate student at Cambridge University's Cavendish Laboratory, had been assigned to investigate the discrepancies between Fermi's 1934 theory of beta decay and what experimenters were actually measuring. Hoyle's advisor, Rudolf Peierls, was a close friend of Hans Bethe, and it was from Peierls that Hoyle learned of Bethe's suspicion that the beta-decay discrepancies might be due to problems with the experiments rather than with Fermi's theory. Peierls asked Hoyle to investigate and Hoyle, together with some Cavendish colleagues, found a way to get the problematic experimental results to line up with Fermi's theory. The Cavendish physicists wanted Hoyle to publish his findings, but this angered Peierls, who accused Hoyle of stealing Bethe's ideas. "As a compromise the paper eventually appeared in 1939 under the authorship of Bethe, Hoyle and Peierls. In it they showed that the experimental results had been wrongly interpreted, and they predicted circumstances under which gamma rays should be observed. The prediction was entirely correct, but Hoyle's relationship with Peierls . . . never recovered from this spat" (Mitton, *Fred Hoyle: A Life in Science,* pp. 54-55). 51025

**4. Bethe, Hans** (1906-2005); **Serge A. Korff** (1906-89); and **Georg Placzek** (1905-55). On the interpretation of neutron measurements in cosmic radiation. Offprint from *Physical Review* 57 (1940). 573-587pp. 268 x 201 mm. Without wrappers as issued. Creased horizontally, but very good. From the library of Nobel Laureate Emilio Segrè (1905-89), with his signature on the first page. $2000




**First Edition, Offprint Issue.** After the discovery of cosmic rays in 1912, "the next two decades saw the study of the increase of cosmic rays with altitude and decreasing atmospheric shielding. Even after thirty years of study, a meaningful theory of the propagation of the [rays'] nucleonic component came only after sufficient understanding of the nuclear force and nuclear theory. Thus, **development began with the historic paper of Bethe, Korff, and Placzek (1940)**, which concerned atmospheric neutrons; these results, although incomplete, remain substantially correct today" (J. W. Wilson *et al., Transport Methods and Interactions for Space Radiations,* p. 239; emphasis ours). This copy is from the library of Nobel Laureate Emilio Segrè, discoverer of the antiproton and the elements technetium and astatine. 51023

**5. Bethe, Hans** (1906-2005) and **Robert E. Marshak** (1916-92). Los Alamos University lecture notes: Electromagnetic theory. Notes by E. D. Klema. Dittoed typescript, numbered "53." [2], 154ff. N.p., n.d. [1948]. 280 x 216 mm. In cardboard folder with metal fasteners, typed label on front cover, light wear at lower corners. Very good. $1750

**First Printing,** and *scarce,* with OCLC recording copies in only four libraries (Cornell, UC Berkeley, Smithsonian, American Institute of Physics). Hans Bethe helped develop both the atom bomb and the hydrogen bomb, and received the Nobel Prize in 1967 for his work in the theory of stellar nucleosynthesis; Robert Marshak, one of Bethe's doctoral students, came up with the explanation for how heat-driven radiation waves (Marshak waves) work in extremely high temperatures. Both Bethe and Marshak were members of the Manhattan Project, the top-secret government program at Los Alamos that designed and built the first atomic weapons during World War II. After the war both men continued their association with the Los Alamos National Laboratory, participating in the so-called "Los Alamos University," a program of technical lectures given as semi-academic courses to junior laboratory personnel. 51008

**6. Bethe, Hans** (1906-2005). Scattering and polarization of protons by nuclei. Reproduced (dittoed) typescript. In two parts: 1 - 56; 57 - 98ff. 281 x 217 mm. Unbound, stapled. Light toning but very good. From the library of Nobel Laureate Owen Chamberlain (1920-2006), with his signature on the first leaf of each part. $1500

**Preprint Edition.** Dittoed preprint of a paper Bethe published in the *Annals of Physics* 3 (1958): 190-240. Bethe, one of the most important nuclear physicists of the 20th century, received the Nobel Prize for physics in 1967 for his work on the theory of stellar nucleosynthesis. This rare preprint is from the library of physicist Owen Chamberlain, who received a share of the Nobel Prize in 1959 for the discovery of the antiproton. 43671

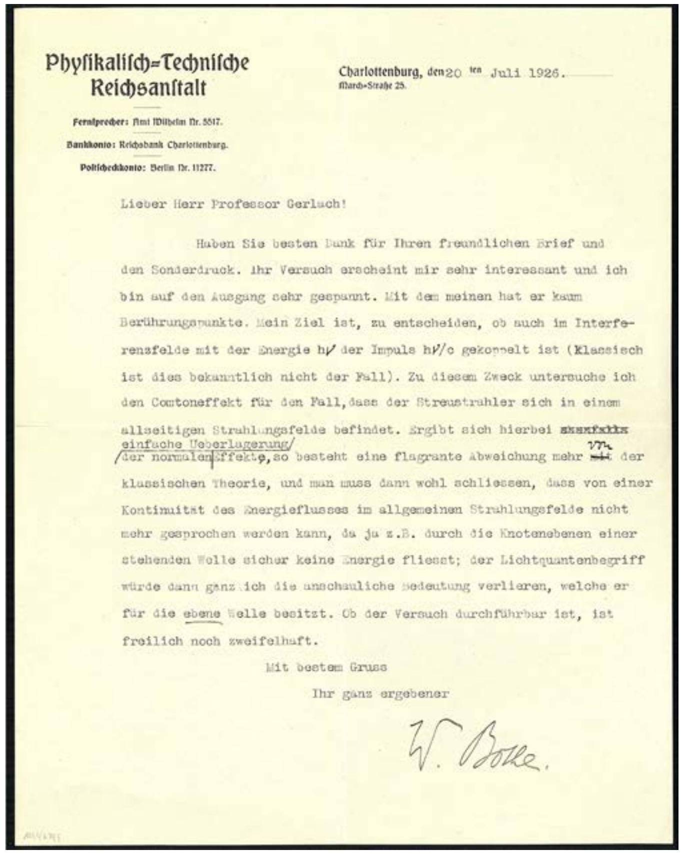
**7. Bohr, Aage** (1922-2009). Rotational states of atomic nuclei. 55pp. 234 x 149 mm. Original printed wrappers. Fine. From the library of Nobel Laureate Owen Chamberlain (1920-2006), with his signature on the front wrapper. $1250

**First Edition.** Aage Bohr, the son of Niels Bohr, received the 1975 Nobel Prize in physics together with Ben Mottelson and James Rainwater for their work on the structure of the atomic nucleus. The prize was based on work that the three had done in the early 1950s, a survey of which is given in the present paper. 43672

**8. Bohr, Niels** (1885-1962); **H. A. Kramers** (1894-1954); and **John C. Slater** (1900-1976). The quantum theory of radiation. In *The London, Edinburgh, and Dublin Philosophical Magazine*, 6th series, 47 (1924): 785-802. Whole number. 785-1056pp. 2 plates. 223 x 146 mm. Original printed wrappers, spine a bit chipped. Very good. $1500

**First Edition in English,** journal issue of the famous Bohr-Kramers-Slater (BKS) paper, in which Bohr and his co-authors attempted to do away with Einstein's light quanta by proposing a new quantum theory of radiation. The existence of light quanta had been proved experimentally by Arthur H. Compton's discovery of the Compton effect, the change in wavelength of x-rays scattered from a target at various angles. "Compton recognized that the shift in the wavelength of x-rays, if scattered by atoms, could be derived only by assuming the existence of radiation in the form of light-quanta, which collide with the electrons in atoms in elementary processes" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 1, p. 554). However, Bohr disputed Compton's interpretation, and in 1924 published his paper with Kramers and Slater arguing that Compton's observations could be explained by assuming that in interactions between atoms and radiation, energy is only statistically conserved. "The most striking feature of this remarkable paper . . . was the renunciation of the classical form of causality in favor of a purely statistical description. Even the distribution of energy and momentum between the radiation field and the 'virtual oscillators' constituting the atomic systems was assumed to be statistical, the conservation laws being fulfilled only on the average" (*Dictionary of Scientific Biography*). The Bohr-Kramers-Slater radiation theory was disproved shortly after its publication by the experiments of Bothe and Geiger and of Compton and Simon, which established that the principles of energy conservation and of causality held true even at the most elementary level. "Nevertheless, this short-lived attempt exerted a profound influence on the course of events; what remained after its failure was the conviction that the classical mode of description of the atomic processes had to be entirely relinquished" (*Dictionary of Scientific Biography*). The BKS paper was first published in German in the *Zeitschrift für Physik* 24 (1924). 50998

**9. Bothe, Walther** (1891-1957). Typed letter signed with manuscript corrections, in German, to Walther Gerlach (1889-1979). 1 page on one sheet; letterhead of the Physikalisch-Technische Reichsanstalt. Charlottenburg, 20 July 1926. 277 x 217 mm. Creased where previously folded, but fine otherwise. $2750



Physikalisch-Technische Reichsanstalt

Charlottenburg, den 20 ten Juli 1926.
March-Straße 25.

Fernsprecher: Amt Wilhelm Nr. 5517.
Bankkonto: Reichsbank Charlottenburg.
Postscheckkonto: Berlin Nr. 11277.

Lieber Herr Professor Gerlach!

Haben Sie besten Dank für Ihren freundlichen Brief und den Sonderdruck. Ihr Versuch erscheint mir sehr interessant und ich bin auf den Ausgang sehr gespannt. Mit dem meinen hat er kaum Berührungspunkte. Mein Ziel ist, zu entscheiden, ob auch im Interferenzfelde mit der Energie hν der Impuls hν/c gekoppelt ist (Klassisch ist dies bekanntlich nicht der Fall). Zu diesem Zweck untersuche ich den Comtoneffekt für den Fall, dass der Streustrahler sich in einem allseitigen Strahlungsfelde befindet. Ergibt sich hierbei einfache Ueberlagerung der normalen Effekte, so besteht eine flagrante Abweichung mehr von der klassischen Theorie, und man muss dann wohl schliessen, dass von einer Kontinuität des Energieflusses im allgemeinen Strahlungsfelde nicht mehr gesprochen werden kann, da ja z.B. durch die Knotenebenen einer stehenden Welle sicher keine Energie fliesst; der Lichtquantenbegriff würde dann gänzlich die anschauliche Bedeutung verlieren, welche er für die ebene Welle besitzt. Ob der Versuch durchführbar ist, ist freilich noch zweifelhaft.

Mit bestem Gruss

Ihr ganz ergebener

W. Bothe.

Letter with excellent scientific content from Walther Bothe, winner of the 1954 Nobel Prize in physics for his "coincidence method," to Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). In it Bothe discusses an experiment he is planning to investigate a certain property of light quanta (photons), part of the extensive researches on the corpuscular theory of light that occupied him in the mid-1920s. The letter can be translated as follows:

> Thank you very much for your kind letter and the reprint. Your attempt seems very interesting and I am very excited about the outcome. It has hardly any points of contact with mine. My goal is to decide whether the impulse hν/c is also coupled to the energy hν in the interference field (as is well known, this is not classically the case). For this purpose I examine an all-round radiation field. If this results in a simple superimposition of the normal effects, there is another flagrant deviation from the classical theory, and one must then conclude that there is no longer any continuity of the energy flow in the general radiation field, since, for example, certainly no energy flows through the nodal planes of a standing wave; the concept of light quanta would then completely lose the graphic meaning which it has for the plane wave. It is of course still doubtful whether the experiment can be carried out.

The Greek letter "ν" in the equation stands for photon frequency, the "h" is Planck's constant and "c" represents the speed of light.

"From 1923 until 1926 Bothe concentrated, especially on experimental and theoretical work on the corpuscular theory of light. He had, some months before the discovery of the Compton effect, observed, in a Wilson chamber filled with hydrogen, the short track of the recoil electrons of X-rays and he did further work on the direction of the emission of photo electrons. Together he and [Hans] Geiger related the Compton effect to the theory of Bohr, Kramers, and Slater, and the results of their work provided strong support for the corpuscular theory of light" (Walther Bothe – Biographical. NobelPrize.org. Nobel Media AB 2021. Sun. 13 Jun 2021). 46299

**10. Broglie, Louis de** (1892-1987). Les principes de la nouvelle mécanique ondulatoire. Offprint from *Journal de physique de le radium*, 6th series, 7 (1926). 321-337pp. 272 x 187 mm. Original printed wrappers, small splits in spine, light sunning. Very good. *Presentation Copy,* inscribed by Broglie on the front wrapper: "Hommage et souvenir de l'auteur L. de Broglie." $1250

**First Edition, Offprint Issue**. Broglie won the Nobel Prize in 1929 for his discovery of the wave nature of electrons, a concept he introduced in his 1924 doctoral thesis. Broglie's discovery was used by Schrödinger two years later in his groundbreaking formulation of wave mechanics. The first form of the Schrödinger theory was non-relativistic, but the present paper Broglie published a modification of Schrödinger's theory to make it include the phenomena of restricted relativity. In the same year Schrödinger published a paper, "Quantisierung als Eigenwertproblem," containing a similar modification. Struik and Wiener, "A relativistic theory of quanta," *Publications from the Massachusetts Institute of Technology* 63 (1927): 1-35. 50957

## *The Antiproton*

**11. Chamberlain, Owen** (1920-2006), **Emilio Segrè** (1905-89) *et al.* Observation of antiprotons. In *The Physical Review,* 2nd series, 100 (1955): 947-50. Whole number. 763-979pp. 268 x 202 mm. Original printed wrappers, vertical crease in back wrapper. Boxed. $1500

**First Edition,** journal issue. Segrè and Chamberlain, colleagues at the University of California, Berkeley, shared the 1959 Nobel Prize in physics for their discovery of the antiproton, a particle with the same mass and spin as the proton but with opposite charge and magnetic moment. Such antiparticles had been predicted in 1928 by Dirac's relativistic theory of the electron, and the first such particle, the positron, had been discovered by C. D. Anderson in 1932. Several rival groups at Berkeley also entered the antiproton hunt, but the Segrè team's experimental ingenuity insured its triumph:

> I decided to attack the problem in two ways. One was based on the determination of the charge and mass of the particle. The other concentrated on the observation of the phenomena attendant on the annihilation of a stopping antiproton. The stopping antiproton and a proton of the target should mutually annihilate each other, and the rest mass of the two particles should transform itself in one of many possible ways into other particles such as pions. These would leave tracks in a photographic emulsion and the annihilation would thus become evident . . .
>
> We started the run on August 25, 1955, and after a few days of tuning up, we began observing antiproton signals. We based the identification on measurement of the velocity, momentum, and charge of a particle. The signals for velocity were oscilloscope traces recording the passage of a particle through a velocity-selecting Cerenkov detector . . . We detected about one antiproton for every few hundred thousand other particles crossing our apparatus . . . We decided to write a letter to the *Physical Review* and an article for *Nature* . . . The mass-spectrograph experiment concluded on October 1, 1955, having proved the existence of the antiproton, and soon thereafter the emulsion work confirmed it (Segrè, *A Mind Always in Motion*, pp. 256-57).

40520

**12. Chamberlain, Owen** (1920-2006); **Emilio Segrè** (1905-89); **Clyde Wiegand** (1915-96); and **Thomas Ypsilantis** (1928-2000). Antiprotons. Offprint from *Nature* 177 (1956). [4]pp. 213 x 141 mm. Bifoliium; without wrappers as issued. With four other papers by Chamberlain as listed below. Very good to fine. $2750

**First Edition, Offprint Issue.** Chamberlain shared the 1959 Nobel Prize for physics with Emilio Segre for their discovery of the antiproton, the antiparticle (same mass, different charge) of the proton. The antiproton had been predicted by Dirac in the 1930s, but it was not until 1955 that Chamberlain and Segre, both physicists at UC Berkeley, were able to confirm the particle's existence experimentally using the University of California's new Bevatron particle accelerator. The above paper, together with no. (3) below, describes some of Chamberlain's antiproton work; no. (4) is his Nobel Lecture. Nos. (1) and (2) below describe Chamberlain's early research on proton-proton scattering, undertaken with experimental physicist Clyde Wiegand.

(1) (with Clyde Wiegand) Proton-proton scattering at 340 Mev. Offprint from *Physical Review* 79 (1950). 81-85pp. 268 x 201 mm. Without wrappers as issued. Tear in lower margins of all leaves, light toning. First edition, offprint issue.

(2) (With Clyde Wiegand). Experiments on proton-proton scattering from 120 to 345 Mev. Offprint from *Physical Review* 83 (1951). 923-932pp. 268 x 201 mm. Without wrappers as issued. First edition, offprint issue.

(3) (With 20 other authors). The antiproton-nucleon annihilation process (antiproton collaboration experiment). Reproduced typescript. 91ff. Berkeley: Printed for the U.S. Atomic Energy Commission, 1956. 281 x 218 mm. Chamberlain's name inscribed in a secretarial hand on first leaf. First edition.

(4) The early antiproton work. Les Prix Nobel en 1959. 107-124pp. Stockholm, 1960. 248 x 166 mm. Original printed wrappers. First edition.

43670

**13. Debye, Peter J. W.** (1884-1966). Zur Theorie der anomalen Dispersion im Gebiete der langwelligen elektrischen Strahlung. Offprint from *Verhandlungen der Deutschen Physikalischen Gesellschaft* 15 (1913). 777-793pp. 229 x 156 mm. Original printed wrappers, slight wear and toning. Very good to fine. From the library of Walther Gerlach (1889-1979), with his stamp on the front wrapper.

$3500

**First Edition, Offprint Issue.** Debye, who trained under Sommerfeld and succeeded Einstein as professor of theoretical physics at the University of Zurich, performed fundamental investigations of the interactions of radiation and matter using X-ray diffraction and other tools, and helped to found modern physical chemistry by developing the fundamental thermodynamics of electrolytic solutions. He received the Nobel Prize for chemistry in 1936 for his contributions to knowledge of molecular structure, and is one of 17 Nobel laureates in chemistry cited by Weber as having performed outstanding work in physics.

In chemistry, *polarity* is a separation of electric charge leading to a molecule having what is known as an *electric dipole moment*; i.e., a separation of negative and positive charges such that the molecule has negatively and positively charged ends. Debye was the first scientist to study this phenomenon extensively, and his first major scientific contribution was the development of equations relating the electric dipole moment to temperature and the dielectric constant (a dielectric is an insulating material; an insulator's dielectric constant, also known as relative permittivity, measures the ability of that insulator to store electric energy in an electrical field). Prior to Debye's work the dielectric constant of a substance had been written using the Clausius-Mossotti equation, which gave correct values for most substances with small dielectric constants but not for liquids with large dielectric constants. Debye came up with improved equations that "not only represented the behavior of the dielectric constant satisfactorily, but also established the existence of a permanent electric dipole in many molecules and provided a means of determining the moment of the dipole and, from this, the geometry of the molecule. After many years of use in molecular structure investigations, the unit in which the dipole moment was expressed came to be called the 'Debye'" (*Dictionary of Scientific Biography*). In the present paper, the second of his three important works on this subject, Debye "showed how the orientation of molecular dipoles in a very high frequency alternating field or in a very viscous medium absorbed energy and gave rise to an anomalous dielectric dispersion and dielectric loss" (*Dictionary of Scientific Biography*).

This copy is from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). 51003

**14. Debye, Peter J. W.** (1884-1966). (1) Über den Einfluss der Wärmebewegung auf die Interferenzerscheinungen bei Röntgenstrahlen. Offprint from *Verhandlungen der Deutschen Physikalischen Gesellschaft* 15 (1913). 678-689pp. 229 x 157 mm. Original printed wrappers. (2) Über die Intensitätsverteilung in den mit Röntgenstrahlen erzeugten Interferenzbildern. Offprint from *Verhandlungen der Deutschen Physikalischen Gesellschaft* 15 (1913). 738-752pp. 229 x 157 mm. Original printed wrappers. (3) Spektrale Zerlegung der Röntgenstrahlung mittels Reflexion und Wärmebewegung. Offprint from *Verhandlungen der Deutschen Physikalischen Gesellschaft* 15 (1913). 229 x 157 mm. Original printed wrappers. Together three offprints. Very slight soiling and creasing but fine otherwise. From the library of Walther Gerlach (1889-1979), with his ownership stamp on the first two papers and blue-pencil signature on the third. $2750

**First Editions, Offprint Issues.** "Within a year of the discovery of X-ray diffraction by crystals by von Laue and the Braggs in 1912, Debye published three papers proving that the thermal movement of the atoms in the crystal affected the X-ray interferences" (*Dictionary of Scientific Biography*). The above three papers, published between 29 July and 18 August 1913, discuss the influence of thermal motion on interference phenomena in X-rays, the intensity distribution in interference images generated with X-rays, and spectral decomposition of X-rays using reflection and thermal movement.

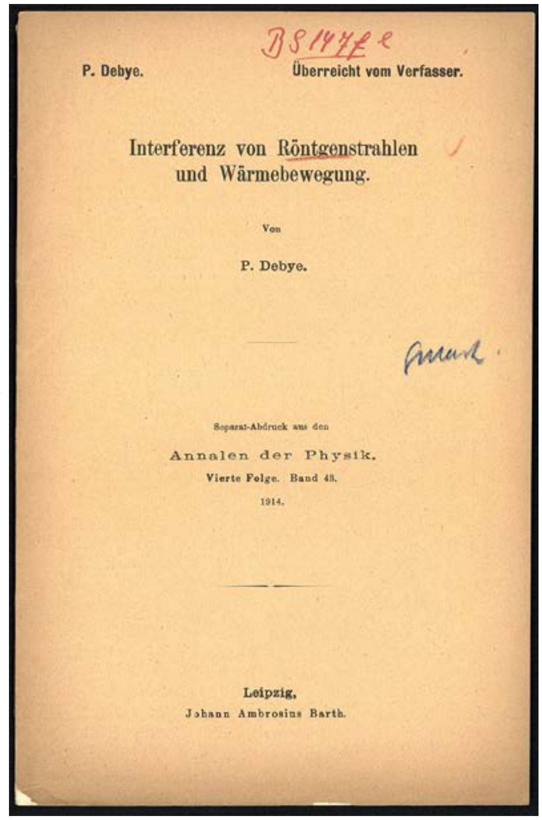
These copies are from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). 51002, 51004, 51007

**15. Debye, Peter J. W.** (1884-1966) and **Arnold Sommerfeld** (1868-1951). Theorie des lichtelektrischen Effektes vom Standpunkt des Wirkungsquantums. Offprint from *Annalen der Physik*, 4th series, 41 (1913). 873-930pp. 222 x 145 mm. Original printed wrappers, a bit chipped, small splits in spine. Very good. From the library of Walther Gerlach (1889-1979), with his characteristic red ink docketing on the front wrapper. $3500

**First Edition, Offprint Issue.** In 1911 Sommerfeld presented his quantum *h*-hypothesis to explain certain properties of X-radiation, but the hypothesis received criticism at the 1912 Solvay Conference, and Sommerfeld's plan to test the *h*-hypothesis experimentally was subsequently derailed by von Laue and Knipping's discovery of X-ray diffraction in crystals. "In 1913 Sommerfeld and Debye expanded upon a theory of the photoelectric effect as a last attempt to make the *h*-hypothesis plausible. They assumed that an atom of metal collects light over a period of time ("accumulation time") until the energy is large enough to emit an electron. Although they were able to derive Einstein's law for the photoelectric effect, the theory amounted to unrealistic conclusions about the accumulation process. Depending on the wavelength of the light with which photoelectrons were emitted, the accumulation time varied widely. X-ray wavelengths amounted to years! Ten years later, when Sommerfeld published the third edition of *Atombau und Spektrallinien*, he mentioned this absurd result as an example of the futile attempts to marry the quantum theoretical with classical conceptions" (Eckert, *Establishing Quantum Physics in Munich: Emergence of Arnold Sommerfeld's Quantum School*, pp. 30-31).

This copy is from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). 51010

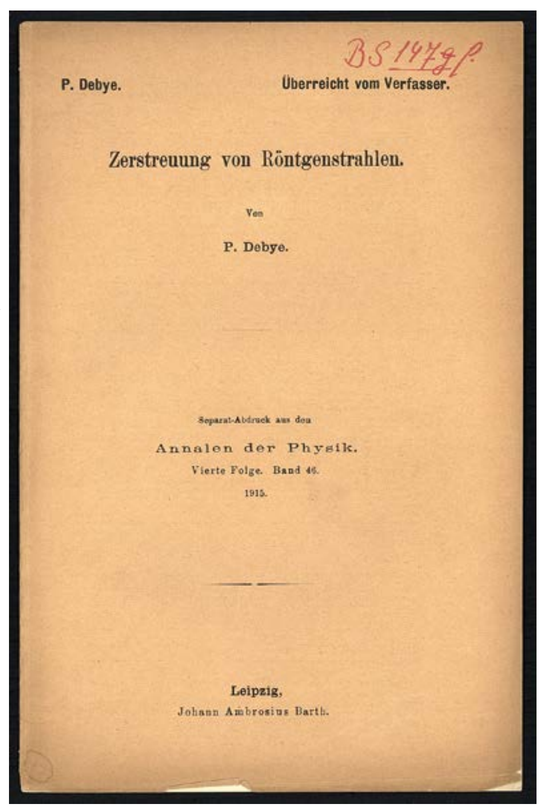
## *The Debye Factor*




**16. Debye, Peter J. W.** (1884-1966). Interferenz von Röntgenstrahlen und Wärmebewegung. Offprint from *Annalen der Physik*, 4th series, 43 (1914). 49-95pp. 224 x 146 mm. Original printed wrappers, small splits at spine, a few chips. Very good. From the library of Walther Gerlach (1889-1979), with his blue-pencil signature on the front wrapper. $4500

**First Edition, Offprint Issue.** Debye's paper introduced what is now known as the Debye factor, an equation giving "the decrease of intensity of the diffraction spots [in X-ray crystallography] as a function of wavelength, diffraction angle, and absolute temperature" (*Dictionary of Scientific Biography*). The Debye factor, also called the Debye-Waller factor, is used in condensed matter physics to describe the attenuation of X-ray scattering or coherent neutron scattering caused by thermal motion. This copy is from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). 51005

## *The Debye Scattering Equation*




**17. Debye, Peter J. W.** (1884-1966). Zerstruung von Röntgenstrahlen. Offprint from *Annalen der Physik*, 4th series, 46 (1915). 809-823pp. 222 x 145 mm. Original printed wrappers, a few tiny marginal chips, slight soiling. Very good. From the library of Walther Gerlach (1889—1979), with his characteristic red ink docketing on the front wrapper. $7500

**First Edition, Offprint Issue.** Debye's paper introduced the Debye scattering equation (DSE), "a way of calculating the scattered intensity from an isotropic [non-crystalline] sample, such as a powder, a liquid or an amorphous material, which does not presume periodicity of the underlying structure . . . Peter Debye's original intuition was that, despite the random arrangement of molecules in gases and liquids, interference between scattering centers can be observed and could reveal details of the atomic arrangement in the molecules" (Scardi et al., p 589). Debye's equation had limited use during most of the 20th century, as it requires a great deal of computing power, but in recent times there has been an enormous growth in the use of the DSE in nanotechnology, chemistry, biology and solid-state physics. This copy is from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). Scardi *et al.*, "Celebrating 100 years of the Debye scattering equation," *Acta crystallographica* A72 (2016): 589-590. 51006

**18. Dirac, Paul A. M.** (1902-84). Relativity quantum mechanics with an application to Compton scattering. Offprint from *Proceedings of the Royal Society* A111 (1926). 405-423pp. 252 x 178 mm. Original printed wrappers, slightly sunned. Very good. Sheet with ink notations and pencil equations laid in. $4750

**First Edition, Offprint Issue.** The first of Dirac's papers to attract widespread attention from his fellow physicists. In the first part of 1926 Dirac had developed his own algebra for quantum mechanics, which he called *q*-number algebra. In the present paper he applied *q*-number algebra to Compton scattering, the scattering of a photon by a charged particle such as an electron, which provided demonstrable proof of the particle nature of electromagnetic radiation (this scattering phenomenon was discovered in 1923 by American physicist Arthur H. Compton, who would receive a Nobel Prize for this achievement).

Dirac showed that Compton scattering followed from his theory. "For the change in wavelength of the radiation, he managed to reproduce Compton's formula, which expresses conservation of energy and momentum. As to the intensity of the scattered radiation, he obtained a result very close to that found by Compton in 1923 but not quite identical with it . . . Dirac's treatment of the Compton effect was recognized to be a work of prime importance. In the period 1926-9, the paper was cited at least 33 times and thus became the first of his papers to have a considerable impact on the physics community" (Kragh, *Dirac: A Scientific Biography*, p. 28). 50822

**19. Dirac, Paul** (1902-84). The elimination of the nodes in quantum mechanics. Offprint from *Proceedings of the Royal Society* A111 (1926). 281-305pp. 252 x 180 mm. Original printed wrappers, some marginal dust-soiling. Very good. $1500

**First Edition, Offprint Issue.** A continuation of Dirac's work on the hydrogen atom, in which he applied his *q*-number algebra "to throw light on some of the spectroscopic problems that had haunted the old quantum theory . . . Most of the results obtained by Dirac in his paper "On the Elimination of the Nodes in Quantum Mechanics" had been found earlier by the German theorists using the method of matrix mechanics, but Dirac was able to improve on some of the results and deduce them from his own system of quantum mechanics" (Kragh, *Dirac: A Scientific Biography*, pp. 27-28). 50821

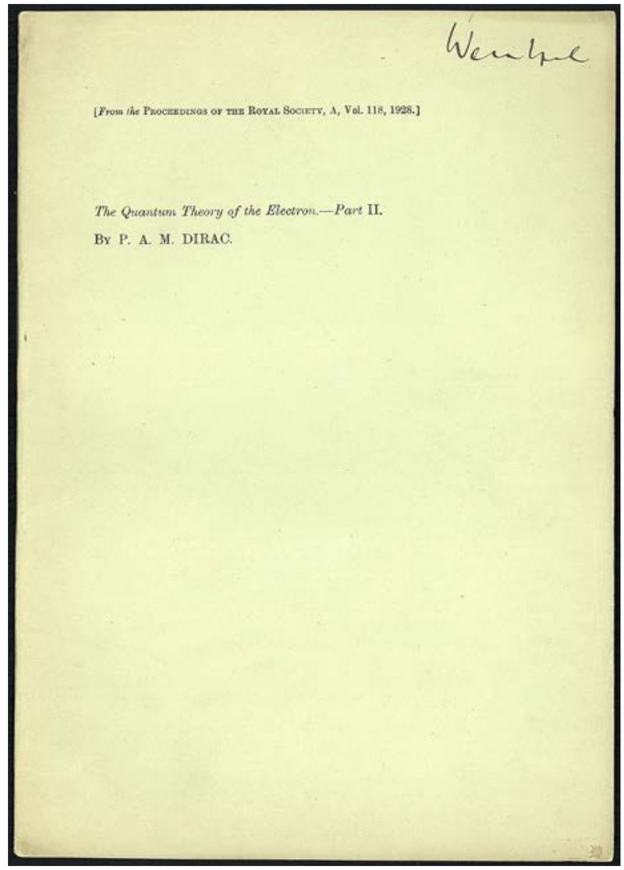
**20. Dirac, Paul A. M.** (1902-84). The Compton effect in wave mechanics. Offprint from *Proceedings of the Cambridge Philosophical Society* 23 (1927). 500-507pp. 219 x 142 mm. Original printed wrappers, one corner slightly bent. Very good. $750

**First Edition, Offprint Issue.** Dirac's treatment of the Compton effect using wave mechanics. "With the new method, he derived exactly the same expressions that he had found in his first paper on the subject" (Kragh, *Dirac: A Scientific Biography*, p. 29). 50836

**21. Dirac, Paul A. M.** (1902-84). The quantum theory of the electron.—Part II. Offprint from *Proceedings of the Royal Society* A118 (1928). 351-61pp. 258 x 178 mm. Original printed wrappers, a little soiled. Very good. From the library of Gregor Wentzel (1898-1978), with his signature on the front wrapper. $7500

**First Edition, Offprint Issue.** The second part of Dirac's two-part paper announcing his relativistic equation of the electron, for which he received the Nobel Prize in physics. The first part, not present here, was published in Vol. A117 (1928) of the *Proceedings of the Royal Society.*

"During the intense period of 1925-26 quantum theories were proposed that accurately described the energy levels of electrons in atoms. These equations needed to be adapted to Albert Einstein's theory of relativity, however. In 1928 Paul Dirac formulated a fully relativistic quantum theory. The equation gave solutions that he interpreted as being caused by a particle equivalent to the electron, but with a positive charge. This particle, the positron, was later confirmed through experiments . . . **The importance of Dirac's work lies essentially in his famous wave equation**, which introduced special relativity into Schrödinger's equation. Taking into account the fact that, mathematically speaking, relativity theory and quantum theory are not only distinct from each other, but also oppose each other, Dirac's work could be considered a fruitful reconciliation between the two theories" (Paul A. M. Dirac – Biographical. NobelPrize.org. Nobel Media AB 2020. Tue. 13 Oct 2020; emphasis ours).




"Dirac's theory of the electron had a revolutionary effect on quantum physics. It was as though the relativistic equation had a life of its own, full of surprises and subtleties undreamed of by Dirac when he worked it out . . . The mathematics of the equation was explored by von Neumann, Van der Waerden, Fock, Weyl and others, and the most important result of this work was the spinor analysis, which built upon a generalization of the properties of the Dirac matrices . . . [The theory] soon turned out to be fruitful for the experimentalists too. In particular, it proved successful in the study of relativistic scattering processes, first investigated by Mott in Cambridge and by Klein, Nishina, and Møller in Copenhagen. By the early thirties, the Dirac equation had become one of the cornerstones of physics, marking a new era of quantum theory" (Kragh, p. 64).

This copy is from the library of theoretical physicist Gregor Wentzel, who made notable contributions to quantum mechanics; he is best known for the Wentzel-Kramers-Brillouin approximation for finding approximate solutions to linear partial differential equations with spatially varying coefficients. Kragh, *Dirac: A Scientific Biography.* Pais, *The Genius of Science,* pp. 49-76. Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, 287-311. 50879

## *Dirac's First Public Presentation of his Relativistic Theory of the Electron*

**22. Dirac, Paul A. M.** (1902-84). Zur Quantentheorie des Elektrons. Offprint from H. Falkenhagen, ed., *Leipziger Forträge 1928: Quantentheorie und Chemie* (Leipzig: S. Hirzel, 1928). 85-96pp. 224 x 148 mm. Without wrappers as issued. Tiny marginal tear in first leaf, but very good. $1500

**First Edition, Offprint Issue.** In the spring of 1928 Heisenberg, who was then teaching at the University of Leipzig, invited Dirac to Leipzig to give a lecture on the relativistic theory of the electron during "University Week" (18 – 23 June). This lecture marked Dirac's first public presentation of his theory. At the end of the lecture Dirac "addressed explicitly a fundamental difficulty of the relativistic wave equations for charged particles . . . Evidently, the negative energy-value problem appeared in Dirac's theory. Though Pauli hoped to solve the difficulty by a noncombination rule, Dirac admitted in Leipzig quite frankly, 'In general, this is not possible . . . It appears that this difficulty can be removed only by a fundamental change in our current ideas, and is connected with the distinction between past and future'" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, p. 306). Dirac gave his lecture in English; it was later translated into German and published in a collected edition of the 1928 Leipzig lectures edited by H. Falkenhagen. 50835


**23. Dirac, Paul A. M.** (1902-84). Quantum mechanics of many-electron systems. Offprint from *Proceedings of the Royal Society*, A, 123 (1929). 714-733pp. 255 x 179 mm. Original printed wrappers. One corner slightly creased, but very good. $4500

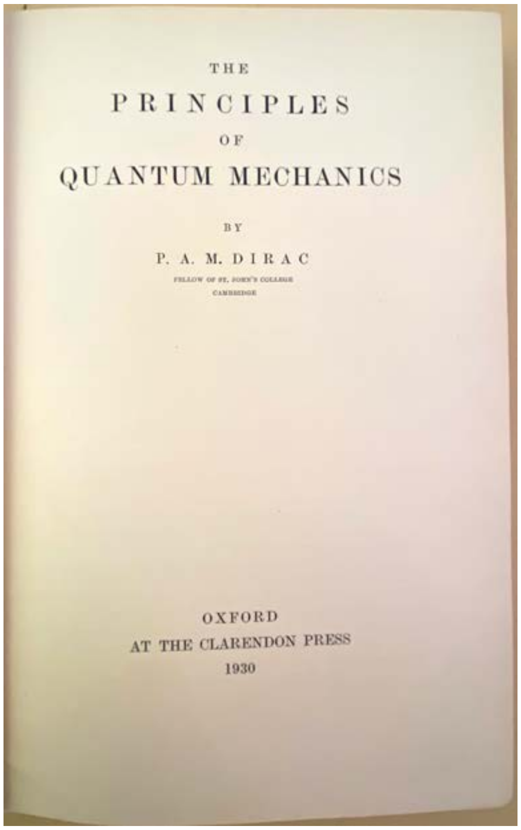
**First Edition, Offprint Issue.** One of Dirac's first papers on atomic theory, and considered by Werner Kutzelnigg to be "Dirac's probably most cited paper." "In his work of 1929, Dirac studied the exchange interaction of identical particles, which he related to the permutations of the coordinates. He introduced permutations such as dynamical variables (operators) and built up a vector model of spin that he applied to the interaction of two or more electrons in an atom. Dirac's theory was extended by Van Vleck, who applied it to complex spectra and ferromagnetism" (Kragh, *Dirac: A Scientific Biography*, p. 76). No copies of the offprint are cited in OCLC. Kutzelnigg, "Perspective on 'Quantum mechanics of many-electron systems': Dirac PAM (1929)," *Proceedings of the Royal Society of London,* series A, 123 (2000): 714. 50818

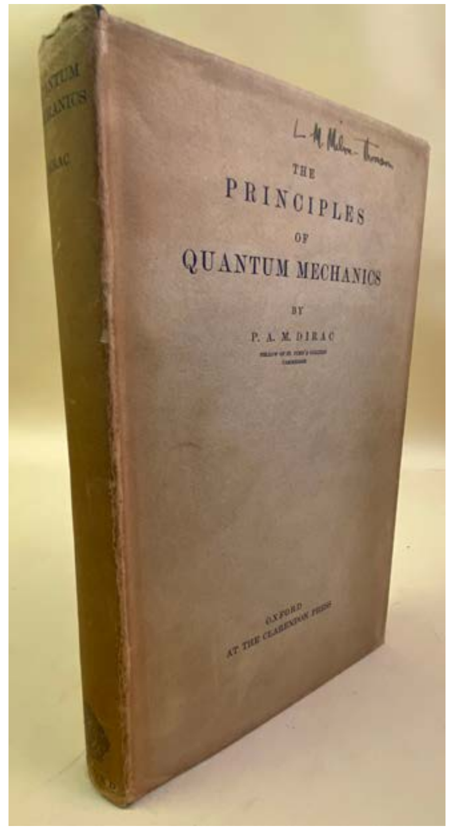
**24. Dirac, Paul A. M.** (1902-84). The basis of statistical quantum mechanics. Offprint from *Proceedings of the Cambridge Philosophical Society* 25 (1929). 62-66pp. 220 x 143 mm. Original printed wrappers, a bit sunned. Very good. $1500

**First Edition, Offprint Issue.** In 1929 John von Neumann published a paper titled "Wahrscheinlichkeitstheoretischer Aufbau der Quantenmechanik" [Probabilistic structure of quantum mechanics] containing his statistical formulation of quantum mechanics, which banned the δ-function Dirac had introduced in his 1927 paper titled "The physical interpretation of quantum dynamics." Dirac "did not revenge by neglecting von Neumann's results. In fall 1928, he rather used his critic's concepts in a paper on 'The Basis of Statistical Quantum Mechanics' . . . In his introduction, he declared:

> The basis of the quantum treatment of [Gibbs's ensembles] has been given by Neumann. The description obtained by Neumann of an ensemble on the quantum theory *is no more complicated than the corresponding classical description.* Thus the quantum theory, which appears to such a disadvantage on the scope of complication when applied to individual systems, recovers its own when applied to an ensemble.

"What Dirac wished to demonstrate in his note was the particular simplicity of the quantum-mechanical description of Gibbs's ensembles, besides stressing simultaneously the analogy between the quantum and the classical treatment" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, p. 459). Dirac submitted his paper to the Cambridge Philosophical Society in October 1928; it was published the following January. Kragh, *Dirac: A Scientific Biography,* p. 76. 50834




**25. Dirac, Paul A. M.** (1902-84). The principles of quantum mechanics. x, 257, [1]pp. Oxford: Clarendon Press, 1930. 237 x 156 mm. Original cloth, dust-jacket (minor wear and chipping). Very fine copy. From the library of British applied mathematician Louis Melville Milne-Thomson (1891-1974), with his signature on the dust-jacket and front free endpaper, and a few annotations in the margins. $7500

**First Edition** of Dirac's classic treatise on quantum mechanics, containing "the first complete exposition of the general formalism of quantum mechanics, presented in a logically consistent and axiomatic fashion" (Jammer, *Conceptual Development of Quantum Mechanics*, p. 366). "Except for Darwin's *Origin of Species,* no book since Newton's *Principia* explained so much of so wide a realm of nature. It is difficult to think of another physics text that conveys more effectively the power of a simple, logical presentation. Probably no other book has ever given its readers a greater appreciation of the aesthetic dimension of theoretical physics" (Schweber, *QED and the Men who Made It*, p. 573). "Present expositions of quantum mechanics largely rely on [Dirac's] masterpiece *The Principles of Quantum Mechanics*" (*Dictionary of Scientific Biography*).

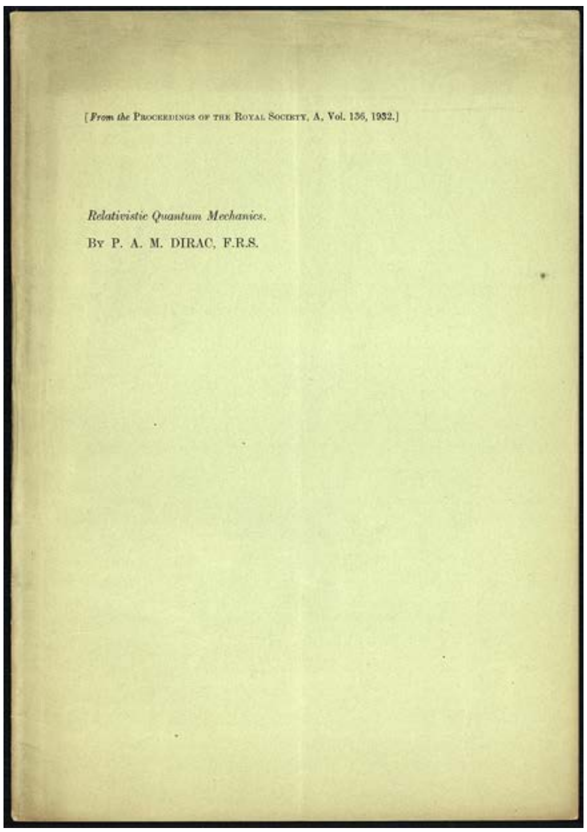
This very fine copy in dust-jacket is from the library of Louis Melville Milne-Thomson, author of several classic textbooks on applied mathematics such as *The Calculus of Finite Differences* (1933), and developer of the Milne-Thomson circle theorem and the Milne-Thomson method for finding a holomorphic function. The excellent condition of Milne-Thomson's copy of Dirac's *Principles of Quantum Mechanics* suggests that he did not use it in his own work, despite the presence of a few marginal notes in what is presumably his hand. 45580

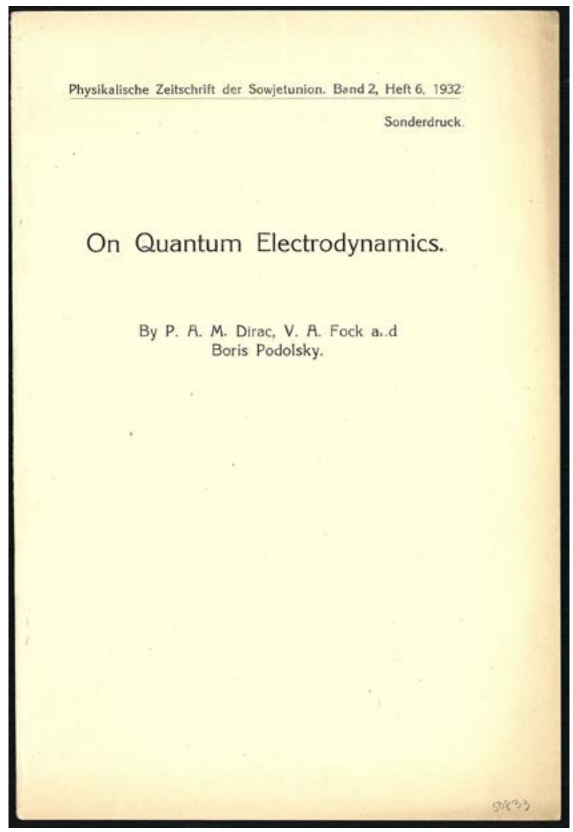
**26. Dirac, Paul A. M.** (1902-84). A theory of electrons and protons. Offprint from *Proceedings of the Royal Society,* A, 126 (1930). 360-365pp. 255 x 177 mm. Original printed wrappers, a bit creased, small tear in back wrapper. Very good. $3750

**First Edition, Offprint Issue.** When Dirac published his revolutionary wave equation of the electron in 1928, he was aware that it gave rise not only to ordinary electrons but to electrons with negative energy. Since at the time physicists believed that matter consisted only of protons and electrons, Dirac was left with the problem of how to explain his equation's negative-energy solution for the relativistic electron without introducing any new, purely theoretical particles. In the present paper he introduced the notion of a "sea" of negative-energy states that would prevent electrons from jumping between positive and negative energy states, and posited that the proton might actually be a negative-energy electron, even though its much greater mass would suggest otherwise. This hypothesis proved to be untenable, but it led to Dirac's prediction in 1931 of an "anti-electron," which came true the following year with Carl David Anderson's discovery of the positron. 50880

**27. Dirac, Paul A. M.** (1902-84). Note on the interpretation of the density matrix in the many-electron problem. Offprint from *Proceedings of the Cambridge Philosophical Society* 27 (1931). 240-243pp. Bifolium; without wrappers as issued. Creased vertically but very good. $500

**First Edition, Offprint Issue.** In this paper Dirac developed methods of using the density matrix first introduced by John von Neumann. Kragh, *Dirac: A Scientific Biography*, p. 148. 50819




## *Inspiration for the Development of Modern Quantum Electrodynamics*

**28. Dirac, Paul A. M.** (1902-84). (1) Relativistic quantum mechanics. Offprint from *Proceedings of the Royal Society,* A, 136 (1932). 453-464pp. 254 x 177 mm. Original printed wrappers, a bit dust-soiled, vertical creasing. Very good. (2) (with **Vladimir Fock** [1898-1974] and **Boris Podolsky** [1896-1966]) On quantum electrodynamics. Offprint from *Physikalische Zeitschrift der Sowjetunion* 2 (1932). 468-479pp. 224 x 152 mm. Original printed self-wrappers, creased vertically, slight soiling. Very good. Together 2 offprints. $7500

**First Editions, Offprint Issues** of Dirac's papers introducing his own approach to quantum electrodynamics, which inspired Schwinger and Tomonaga's Nobel Prize-winning work on the development of modern QED in the 1940s.

Dirac founded quantum electrodynamics in 1927 with his landmark paper, "The quantum theory of the emission and absorption of radiation," but after this paper he did not return to the subject of QED until 1932, when he published "Relativistic quantum mechanics" (no. [1] above). In this paper Dirac explicitly rejected Heisenberg and Pauli's approach to QED set forth in their two-part joint paper of 1929-30, replacing it with his own formulation, which he believed provided a better foundation for quantum field theory. Dirac's alternative approach to QED was soon shown to be mathematically equivalent to the Heisenberg-Pauli theory; however, Dirac felt that his version was superior from a conceptual point of view and continued to develop it in "On quantum electrodynamics" (no. [2] above), co-authored with Russian physicists Vladimir Fock and Boris Podolsky.

The formal innovations outlined in Dirac's two papers "proved to be important for the later development of quantum electrodynamics. When the emergence of modern renormalization techniques finally provided a breakthrough for the theory in 1947-8, Dirac's papers served as an important source of inspiration. Julian Schwinger, one of the architects of the new theory, was inspired by the Dirac-Podolsky-Fock formulation; he developed it greatly and also coined the term 'interaction representation.' Sin-Itoro Tomonaga, another of the fathers of modern quantum electrodynamics, was fascinated by Dirac's 1932 paper, which 'attracted my interest because of the novelty of its philosophy and the beauty of its form. The long and troublesome road toward renormalization thus took its start in aspects of Dirac's work" (Kragh, p. 138). Kragh, *Dirac: A Scientific Biography.* 50820, 50833

**29. Dirac, Paul A. M.** (1902-84). The Lagrangian in quantum mechanics. Offprint from *Physikalische Zeitschrift der Sowjetunion* 3 (1933). 64-72pp. 229 x 152 mm. Original printed self-wrappers, light marginal toning. Very good. $4500

**First Edition, Offprint Issue.** Although Dirac had established the basic framework of quantum mechanics in the 1920s, he never stopped looking "for alternative or more general formulations of quantum mechanics that might be more suitable for relativistic applications" (*Dictionary of Scientific Biography*). "In an investigation in 1933 of the formal quantum mechanical analogue of classical Lagrangian theory, Dirac argued that the Lagrangian method was in some respects more fundamental than the standard Hamiltonian method . . . Buried in the pages of the *Physikalische Zeitschrift der Sowjetunion,* Dirac's Lagrangian theory was not much noticed in the thirties, but years later it was studied by the young Richard Feynman, who developed it into the space-time approach to quantum field theory for which he received the Nobel Prize" (Kragh, *Dirac: A Scientific Biography*, p. 138). 50839

**30. Dirac, Paul A. M.** (1902-84). Statement of a problem in quantum mechanics. Offprint from *Journal of the London Mathematical Society* 8 (1933). 274-277pp. 264 x 180 mm. Original printed wrappers, chipped and sunned, upper margin a bit creased. Light toning but very good. $750

**First Edition, Offprint Issue.** In this paper on a problem in quantum electrodynamics, "Dirac argued that the existing quantum transformation theory was not suited for a relativistic treatment. He stated clearly his dissatisfaction with the existing Heisenberg-Pauli formation or relativistic quantum mechanics, which, he wrote, 'seems to be possible only if one introduces enormous complexity into the equations and sacrifices the directness of physical interpretation which was so satisfactory a feature of the non-relativistic theory" (Kragh, *Dirac: A Scientific Biography,* p. 139). 50925

**31. Dirac, Paul A. M.** (1902-84). Lectures on quantum electrodynamics . . . 1934-1935. Notes by Dr. Boris Podolsky first semester and Dr. Nathan Rosen second semester. Mimeograph typescript. [1], 30, 2-1 – 2-41ff. Princeton, NJ: Institute for Advanced Study, 1935. 276 x 216 mm. Original light cardboard covers, cloth backstrip, lower portion a bit faded, one corner creased. Very good. Title and owner's name (Beryl H. Dickinson) lettered in ink on the front cover. $2750

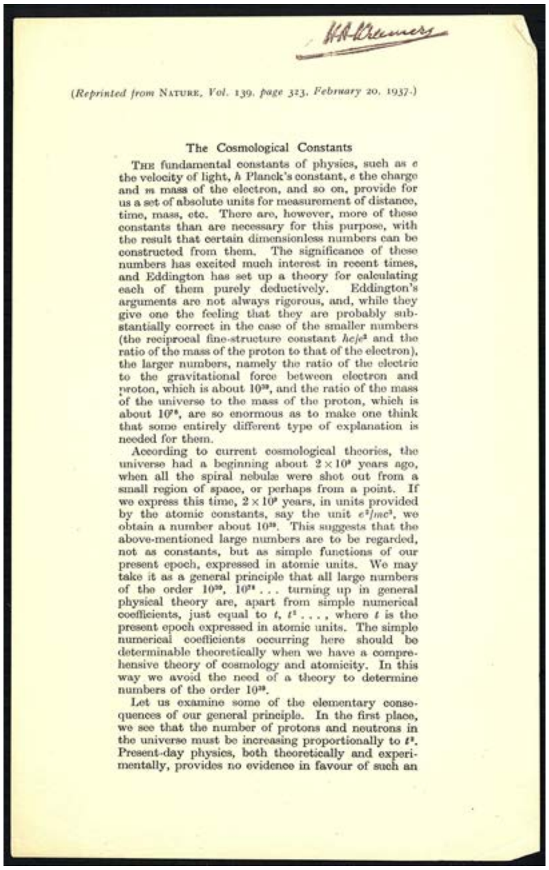
**First Printing; Apparently Unpublished.** In the academic year 1934-35 Dirac spent two terms at Princeton's Institute for Advanced Study, where he lectured on quantum electrodynamics. The present notes of Dirac's Princeton lectures were taken by Boris Podolsky and Nathan Rosen, two of the authors of the famous Einstein-Podolsky-Rosen paper attacking quantum theory ("Can quantum-mechanical description of physical reality be considered complete?"), which was published in 1935. 45919

**32. Dirac, Paul A. M.** (1902-84). (1) The electron wave equation in De-Sitter space. Offprint from *Annals of Mathematics* 36 (1935). 657-669pp. 256 x 176 mm. Original printed wrappers, slightly sunned. (2) Wave equations in conformal space. Offprint from *Annals of Mathematics* 37 (1936). 429-442pp. 255 x 175 mm. Original printed wrappers, slightly sunned. Together 2 items. Very good. $2850

**First Editions, Offprint Issues.** In the fall of 1934 Dirac accepted an appointment at Princeton's Institute for Advanced Study, where he spent two terms attached to the School of Mathematics. "Dirac's stay at Princeton resulted in two papers, both of which were published in the *Annals of Mathematics*, signifying that they were contributions to mathematical physics . . . Dirac examined two geometries, de Sitter space and conformal space . . .These more general spaces had previously been applied to general relativity and electromagnetism, and Dirac now showed that the fundamental questions of quantum mechanics could also be formulated in de Sitter space and conformal space" (Kragh, *Dirac: A Scientific Biography*, p 168). De Sitter space, named for astronomer Willem de Sitter, serves as one of the simplest mathematical models of the universe consistent with the universe's accelerating expansion; conformal geometry, which is concerned with angles rather than distances, deals with the set of angle-preserving transformations in conformal space. 50823, 50824

**33. Dirac, Paul A. M.** (1902-84). Relativistic wave equations. Offprint from *Proceedings of the Royal Society of London*, A, 155 (1936). 447-459pp. 256 x 177 mm. Original printed wrappers, slightly worn. Very good. From the library of H. A. Kramers (1894-1952), with his name in pencil on the front wrapper and pencil notes and equations on a few leaves. $3500

**First Edition, Offprint Issue.** "At the beginning of 1936 Dirac worked out a new generalization of his linear relativistic wave equation. By the mid-1930s, the linear Dirac equation of 1928 was known to describe the behavior of particles with half-integral spin, such as the electron, the positron, and presumably also the proton. The emergence of new elementary particles (the positron and the neutron) made physicists more receptive to the idea that other new particles, perhaps with spin different from one half, might exist in nature. Such hypothetical particles attracted theoretical interest, which in 1936 resulted in three attempts [by Dirac, G. Petiau, and A. Proca] to generalize the wave equation to cover particles with arbitrary spin . . . Dirac applied the spinor formalism, introduced by Van der Waerden in 1929, in order to construct a system of relativistic wave equations linear in the energy operator. He proved that these general equations were also able to describe particles with spin greater than one-half and with either zero or nonzero rest mass . . . **When the meson made its entry into Western physics in the late 1930s, the generalized wave equations became more interesting from a physical point of view**" (Kragh, *Dirac: A Scientific Biography*, pp. 168-169; emphasis ours). 50923

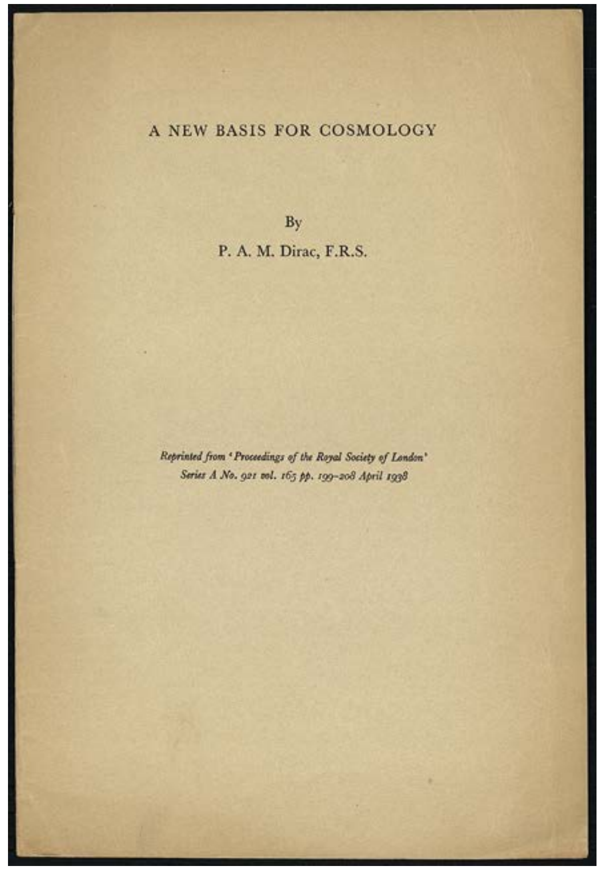

(*Reprinted from* NATURE, *Vol.* 139, *page* 323, *February* 20, 1937.)

The Cosmological Constants

THE fundamental constants of physics, such as $c$ the velocity of light, $h$ Planck's constant, $e$ the charge and $m$ mass of the electron, and so on, provide for us a set of absolute units for measurement of distance, time, mass, etc. There are, however, more of these constants than are necessary for this purpose, with the result that certain dimensionless numbers can be constructed from them. The significance of these numbers has excited much interest in recent times, and Eddington has set up a theory for calculating each of them purely deductively. Eddington's arguments are not always rigorous, and, while they give one the feeling that they are probably substantially correct in the case of the smaller numbers (the reciprocal fine-structure constant $hc/e^2$ and the ratio of the mass of the proton to that of the electron), the larger numbers, namely the ratio of the electric to the gravitational force between electron and proton, which is about $10^{39}$, and the ratio of the mass of the universe to the mass of the proton, which is about $10^{78}$, are so enormous as to make one think that some entirely different type of explanation is needed for them.

According to current cosmological theories, the universe had a beginning about $2 \times 10^9$ years ago, when all the spiral nebulæ were shot out from a small region of space, or perhaps from a point. If we express this time, $2 \times 10^9$ years, in units provided by the atomic constants, say the unit $e^2/mc^3$, we obtain a number about $10^{39}$. This suggests that the above-mentioned large numbers are to be regarded, not as constants, but as simple functions of our present epoch, expressed in atomic units. We may take it as a general principle that all large numbers of the order $10^{39}$, $10^{78}$ . . . turning up in general physical theory are, apart from simple numerical coefficients, just equal to $t$, $t^2$ . . . , where $t$ is the present epoch expressed in atomic units. The simple numerical coefficients occurring here should be determinable theoretically when we have a comprehensive theory of cosmology and atomicity. In this way we avoid the need of a theory to determine numbers of the order $10^{39}$.

Let us examine some of the elementary consequences of our general principle. In the first place, we see that the number of protons and neutrons in the universe must be increasing proportionally to $t^2$. Present-day physics, both theoretically and experimentally, provides no evidence in favour of such an


A NEW BASIS FOR COSMOLOGY

By

P. A. M. Dirac, F.R.S.

*Reprinted from 'Proceedings of the Royal Society of London' Series A No. 921 vol. 165 pp. 199–208 April 1938*

# *The Large Number Hypothesis*

**34. Dirac, Paul A. M.** (1902-84). (1) The cosmological constants. Offprint from *Nature* 139 (1937). Single sheet. [2]pp. 215 x 134 mm. Corners a bit creased, light toning but very good. From the library of H. A. Kramers (1894-1952), with his stamp on the first page. (2) A new basis for cosmology. Offprint from *Proceedings of the Royal Society of London*, series A, 165 (1938). 199-208pp. 256 x 173 mm. Original printed wrappers. Faint creasing, light marginal toning but very good. Together 2 items. $7500

**First Edition, Offprint Issue.** Dirac's brief 1937 paper (no. [1]) marks the announcement of his Large Number Hypothesis (LNH) relating ratios of size scales in the Universe to those of force scales—in other words, positing a relationship between cosmic and atomic constants based on the then-new idea of an expanding universe. The following year Dirac published an expanded version of the LNH in "A new basis for cosmology" (no. [2]).

Building on Arthur Eddington's belief in "a grand unification of atomic physics and cosmology," Dirac "focused on dimensionless numbers built from the fundamental constants of both atomic and cosmic phenomena; and he observed that there was a cluster of numbers around $10^{39}$, including the age of the universe in atomic time units and the ratio of electric forces to gravitational ones inside atoms. In 1937 he proposed the 'large-number hypothesis,' according to which numbers in the same cluster should be simply related. Consequently, the gravitation constant had to vary in time . . . contrary to general relativity" (*Dictionary of Scientific Biography*).

"Dirac claimed that the regularity exhibited by these large dimensionless numbers was not purely fortuitous . . . [regarding] them to be contingent quantities, dependent on the history of the universe . . . Later, Dirac preferred to call this assumption the Large Number Hypothesis (LNH in what follows). In 1938 he named it the Fundamental Principle, emphasizing that it should be understood as a postulate of correlation between any two of the large dimensionless numbers, whether or not $\tau_0$ [the age of the universe expressed in atomic units of time] was involved: 'Any two of the very large dimensionless numbers occurring in Nature are connected by a simple mathematical relation, in which the coefficients are of the order of magnitude unity.' Dirac thus accounted for the vastness of the ratio between electromagnetic and gravitational forces as a consequence of the age of our present universe" (Kragh, *Dirac: A Scientific Biography,* p. 228). Although Dirac's cosmological theory was not well received on its publication, his Large Number Hypothesis has continued to stimulate scientific thought, inspiring—among other things—the idea of the "fine-tuned" universe. 50922; 50921

**35. Dirac, Paul A. M.** (1902-84). Complex variables in quantum mechanics. Offprint from *Proceedings of the Royal Society of London* 160 (1937). 48-59pp. 256 x 179 mm. Original printed wrappers, slightly creased. Very good. From the library of H. A. Kramers (1894-1952), with his stamp on the front wrapper. $950

**First Edition, Offprint Issue.** "In quantum mechanics the state of a quantum system is usually represented by a function of real variables, the domains of which are the eigenvalues of certain observables. In 1937, Dirac suggested that the condition of realness be dropped and that the variables be considered as complex quantities so that the representatives of dynamical variables could be worked out with the powerful mathematical machinery belonging to the theory of complex functions. If dynamical variables are treated as complex quantities, they can no longer be associated with physical observables in the usual sense. Dirac admitted this loss of physical understanding but did not regard the increased level of abstraction as a disadvantage . . . With his new method Dirac showed how the hydrogen atom could be treated in an elegant way, but he did not derive new physical results" (Kragh, *Dirac: A Scientific Biography*, pp. 282-283).

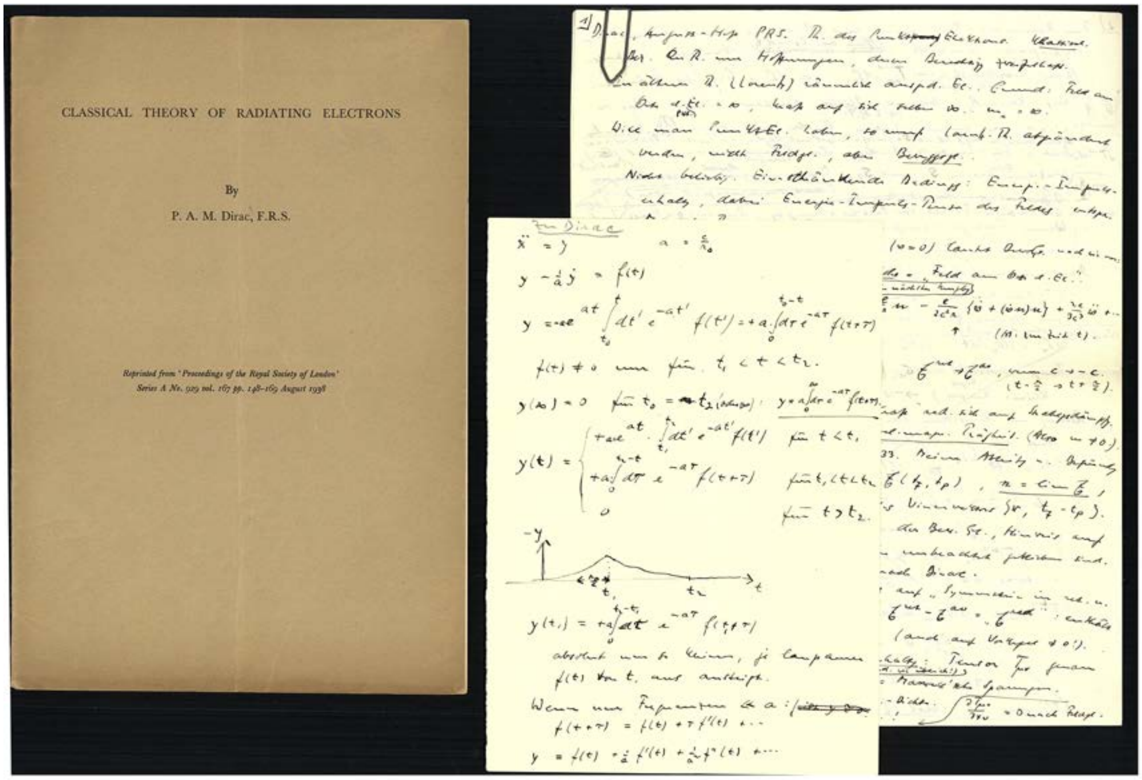
This copy of Dirac's paper is from the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory. 50924

## *Wentzel's Copy, With His Eight-Page Manuscript Commentary Laid In*

**36. Dirac, Paul A. M.** (1902-84). Classical theory of radiating electrons. Offprint from *Proceedings of the Royal Society of London*, A, 167 (August 1938). 148-169pp. 257 x 172 mm. Original printed wrappers, vertically creased, slight soiling. Very good. From the library of physicist Gregor Wentzel (1898-1978), with his name in pencil (erased) on the front wrapper; **8-page manuscript (in German) in Wentzel's hand commenting on Dirac's paper laid in**. $7500

**First Edition, Offprint Issue.** "[Dirac's] paper of 1938 was an important contribution to electron theory and is still considered to be a classic" (Kragh, *Dirac: A Scientific Biography,* p. 189). In an attempt to resolve the issues with infinities that plagued quantum electrodynamics in the 1930s, Dirac set out to come up with a better classical theory of the electron that could then be quantized. In the present paper he created a finite theory of point electrons that yielded the "Lorentz-Dirac" equation (also known as the "Abraham-Lorentz-Dirac equation of motion"), which "was exact and involved neither infinities nor structure-dependent terms" (Kragh, p. 194). Unfortunately, Dirac's theory, "in spite of its formal beauty, . . . involved unphysical 'runaway' solutions (spontaneously accelerating electrons) that could be eliminated (at the classical level) only at the price of making supraluminal [faster than the speed of light] signals possible" (*Dictionary of Scientific Biography*). Dirac continued to work on classical electron theories until the 1960s.

This important association copy is from the library of German physicist Gregor Wentzel, whose notable contributions to quantum mechanics include the Wentzel-Kramers-Brillouin approximation for finding approximate solutions to linear differential equations with spatially varying coefficients. In a three-part paper on the




intrinsic forces of elementary particles ("Über die Eigenkräfte der Elementarteilchen"), published in 1933-34, Wentzel had introduced the λ-limiting technique, which Dirac used in the present paper to eliminate infinities for a single electron up to the order of $e^2$. As Dirac told Bohr in a letter written on 5 December 1938, "the limiting procedure is effectively the same as Wentzel's, but it is now put into exact Hamiltonian form" (quoted in Kragh, p. 195). The manuscript laid into this copy, headed "Dirac, August-Heft PRS," is filled with Wentzel's commentary and equations; it includes a reference to Wentzel's own paper ("NB: Ergebnis = meinem von 1933" [NB: Result = mine from 1933]). 50825

**37. Dirac, Paul A. M.** (1902-84). Classical theory of radiating electrons. Offprint from *Proceedings of the Royal Society of London*, A, 167 (1938). 148-169pp. 257 x 172 mm. Original printed wrappers, slightly stained. Very good. From the library of H. A. Kramers (1894-1952), with his stamp on the front wrapper and his pencil notes and calculations on several pages. $3500

**First Edition, Offprint Issue.** This copy is from the library of Dutch physicist H. A. Kramers, one of the main architects, together with Pauli, Heisenberg and Schrödinger, of quantum mechanics. Kramers annotated this copy with a number of notes and equations in pencil, which can be found on pp. 155 and pp. 164-168. 50919

**38. Dirac, Paul A. M.** (1902-84); **Rudolf Peierls** (1907-95); and **Maurice H. L. Pryce** (1913-2003). On Lorentz invariance in the quantum theory. Offprint from *Proceedings of the Cambridge Philosophical Society* 38 (1941). 193-200 pp. 257 x 180 mm. Without wrappers as issued. Vertically creased, light toning but very good. $950

**First Edition, Offprint Issue.** In the 1930s Subramanyan Chandrasekhar, who would win the 1983 Nobel Prize in physics for his work on the structure and evolution of stars, came up with a generalized standard model for certain types of stars that made use of relativistic Fermi-Dirac statistics and other quantum-mechanical concepts. Arthur Eddington, the distinguished British astrophysicist, objected to Chandrasekhar's methods and his conclusions, arguing against them both in person and in print. In the present paper Dirac, Peierls and Pryce countered Eddington's arguments, "[showing] in particular that the dynamics of atomic systems did allow one to perform correctly all of the procedures [Eddington] had criticized. Thus, they simply confirmed the general opinion of the community of physicists, namely: 'Eddington's system of mechanics is in many respects completely different from quantum mechanics'" (Mehra & Rechenberg, *The Historical Development of Quantum Theory*, 6, p. 887). 50831

**39. Dirac, Paul A. M.** (1903-84). Quantum electrodynamics. *Communications of the Dublin Institute for Advanced Sciences*, series A, no. 1. Dublin: Dublin Institute for Advanced Studies, 1943. [2], 36pp. 257 x 183 mm. Original printed wrappers, slight wear. Very good. $250

**First Edition.** A continuation of Dirac's 1939 theory of the classical electron. Kragh, *Dirac: A Scientific Biography*, p. 175. 50830

**40. Dirac, Paul A. M.** (1902-84). Lectures on quantum electrodynamics . . . Fall, 1946. Notes taken by S. Kusaka. Mimeograph typescript. [2], 57ff. Princeton, NJ: Institute for Advanced Study, 1946. 282 x 220 mm. In light cardboard binder with metal fastenings, slightly worn. Very good. $3500

**Rare First Printing**, **Apparently Unpublished;** with only two physical copies (Princeton IAS, U. Sydney) recorded in OCLC. Dirac was a visiting professor at the Institute for Advanced Study from fall 1948 to summer 1948. The notes for his fall 1946 lectures on QED were taken by Shuichi Kusaka (1915-47), an assistant professor of physics at Princeton; Princeton's Kusaka Memorial Physics Prize is named for him. 50974

**41. Dirac, Paul A. M.** (1902-84). The development of quantum mechanics. Offprint from *Contributi del Centro Linceo Interdisciplinare di Scienze Mathematiche e loro Applicazioni*, no. 4 (1974). 11pp. 270 x 185 mm. Original printed wrappers. Very good. $250

**First Edition, Offprint Issue.** From the library of Nobel Laureate Emilio Segrè (1905-89), discoverer of the antiproton and the elements technetium and astatine. 46551

**42. Einstein, Albert** (1879-1955). Über eine Methode zur Bestimmung des Verhältnisses der transversalen und longitudinalen Masse des Elektrons. Offprint from *Annalen der Physik* 21 (1906). 583-586pp. 223 x 145 mm. Original printed wrappers, chipped, spine splitting, minor spotting. Light toning but very good. $3750

**First Edition, Rare Offprint Issue.** In his landmark 1905 paper on special relativity, Einstein used the velocity-dependent concepts of *transverse* and *longitudinal* mass for the moving electron (these terms have now been replaced with the concept of *relativistic mass,* first defined by Lewis and Tolman in 1909). In the present paper Einstein proposed an experimental method for determining the ratio of the transverse to the longitudinal mass, and invited experimentalists to verify his special theory of relativity. Einstein later abandoned velocity-dependent mass concepts, stating in 1948 that "it is better to introduce no other mass concept than the 'rest mass' *m*" (quoted in L. B. Okun, "The concept of mass," *Physics Today* (1989): 31-36). Lavenda, *A New Perspective on Relativity,* pp. 7-8. Weil, *Albert Einstein Bibliography,* 14. 43289

## *Two Classic Einstein Papers*

**43. Einstein, Albert** (1879-1955). (1) Zur Theorie der Lichterzeugung und Lichtabsorption. (2) Das Prinzip von der Erhaltung der Schwerpunktsbewegung und die Trägheit der Energie. In *Annalen der Physik* 20 (1906): 199-206; 627-633pp. Whole volume. 210 x 142 mm. Original cloth, spine faded, extremities worn. Minor foxing and toning, but very good. $1500

**(1) First Edition,** journal issue. The brilliant follow-up to Einstein's landmark 1905 paper on the photoelectric effect. In the 1905 paper Einstein had explained the photoelectric effect—the emission of electrons from a metal when irradiated by light—by making the revolutionary proposal that light, rather than consisting of continuous waves, was instead made up of discrete particles of energy ("light quanta"), which transferred their entire payload of energy to an electron on impact. In the 1905 paper Einstein made use of Planck's mathematical formula for blackbody radiation, which had introduced the concept of energy quanta, but he was only able to derive part of the formula. In his 1906 paper Einstein "used his statistical mechanics to demonstrate that when light interacts with matter, Planck's **entire formula can arise only from the existence of light quanta—not from waves**" (Cassidy; emphasis ours). Einstein had realized, as he stated in the present paper, that "'Planck's theory makes implicit use of the . . . light-quantum hypothesis' . . . his acceptance of Planck's [formula], albeit as a hypothesis, led to a major advance in his own work" (Pais, *Subtle is the Lord,* p. 378). In 1921 Einstein was awarded the Nobel Prize in physics for his work on the photoelectric effect. Cassidy, David, "Einstein on the Photoelectric Effect." *Einstein: Image and Impact*. American Institute of Physics, n.d. Web. Accessed 09 July 2014. Shields, "Writings of Albert Einstein" (in *Albert Einstein: Philosopher-Scientist* [1948], pp. 689-758), no. 13; also included in Shields' "Chronological list of principal works" on p. 757. Weil, *Albert Einstein: A Bibliography*, no. *12.

**(2) First Edition,** journal issue of Einstein's second paper on the inertia of energy, following his 1905 paper "Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?" [Is the inertia of a body dependent on its energy content?]. In the present paper Einstein presented another argument in support of the proposition that a body's energy depends on its energy content. "About a year after he first introduced the inertia of energy, Einstein published a paper, entitled "The Principle of the Conservation of the Center of Gravity and the Inertia of Energy," in which he showed that $E = mc^2$ is necessary and sufficient to ensure that the center-of-mass theorem holds for systems in which 'not only mechanical, but also electromagnetic processes take place' . . . As Einstein acknowledges, his paper is similar to Poincaré's contribution to the Lorentz *Festschrift* [1900]. Einstein showed that in order to avoid the kind of violations of the center-of-mass theorem discussed by Poincaré, one has to assume that energy has inertia" (Janssen, pp. 39-40). Janssen, "The Trouton experiment, $E = mc^2$, and a slice of Minkowski space-time," in *Revisiting the Foundations of Relativistic Physics: Festschrift in Honor of John Stachel* (2003), pp. 27-54. Weil, *Albert Einstein Bibliography,* 13. 50414

**44. Einstein, Albert** (1879-1955). Über eine Methode zur Bestimmung des Verhältnisses der transversalen und longitudinalen Masse des Elektrons. In *Annalen der Physik* 21 (1906): 583-586. Whole volume. 213 x 142 mm. Original cloth, spine faded and cracking. Light toning and foxing but very good. $1500

**First Edition,** journal issue. In his landmark 1905 paper on special relativity, Einstein used the velocity-dependent concepts of *transverse* and *longitudinal* mass for the moving electron (these terms have now been replaced with the concept of *relativistic mass,* first defined by Lewis and Tolman in 1909). In the present paper Einstein proposed an experimental method for determining the ratio of the transverse to the longitudinal mass, and invited experimentalists to verify his special theory of relativity. Einstein later abandoned velocity-dependent mass concepts, stating in 1948 that "it is better to introduce no other mass concept than the 'rest mass' *m"* (quoted in L. B. Okun, "The concept of mass," *Physics Today* (1989): 31-36). Lavenda, *A New Perspective on Relativity,* pp. 7-8. Weil, *Albert Einstein Bibliography,* 14. 50413

**45. Einstein, Albert** (1879-1955). Berichtigung zu meiner Arbeit: "Die Plancksche Theorie der Strahlung etc." Offprint from *Annalen der Physik* 22 (1907). Single sheet (p. 800). Unbound as issued. 223 x 145 mm. Lower corner lightly creased, but very good. $1500

**First Edition, Rare Offprint Issue.** Einstein's important correction to his paper on specific heats, "Die Plancksche Theorie der Strahlung und die Theorie der spezifischen Wärme" (1907; see Weil *15), which "made clear for the first time that quantum concepts have a far more general applicability" (Pais, p. 394). "Einstein initially believed that his oscillating lattice points [in a three-dimensional crystal lattice] were electrically charged ions. A few months later he published a correction to his paper, in which he observed that this was an unnecessary assumption . . . Einstein's correction freed the quantum rules (in passing, one might say) from any specific dependence on electromagnetism" (Pais, p. 396). Pais, *Subtle is the Lord,* pp. 394-396. Weil, *Albert Einstein Bibliography*,*15(n). 43297

**46. Einstein, Albert** (1879-1955). Theoretische Bemerkungen über die Brownsche Bewegung. Offprint from *Zeitschrift für Elektrochemie* (1907). Single sheet (pp. 41-42). 287 x 206 mm. Chipped, several marginal tears, some toning. Fair. $1500

**First Edition, Offprint Issue**. "In 1907, Einstein published a paper entitled 'Theoretical Observations on the Brownian Motion' in which he considered the instantaneous velocity of a Brownian particle. Einstein showed that by measuring this quantity, one could prove that 'the kinetic energy of the motion of the center of gravity of a particle is independent of the size and nature of the particle and independent of the nature of its environment.' This is one of the basic tenets of statistical mechanics, known as the equipartition theorem. However, Einstein concluded that due to the very rapid randomization of the motion, the instantaneous velocity of a Brownian particle would be impossible to measure in practice . . . "(Einstein: *The Formative Years*). Weil, *Albert Einstein Bibliography*, 20. 43312

**47. Einstein, Albert** (1879-1955) and **Jakob Johann Laub** (1884-1962). Über die elektromagnetischen Grundgleichungen für bewegter Körper. Offprint from *Annalen der Physik*, 4th series, 26 (1908). 532-540pp. 225 x 146 mm. Original printed wrappers. Fine. $3750

**First Edition, Offprint Issue.** Einstein's first paper written jointly with a collaborator, on the relativistic electrodynamics of ponderable media. "In 1908 [Laub] wrote works together with Einstein on the basic electromagnetic equations, which was aimed to replace the four-dimensional formulation of the electrodynamics by Minkowski by a simpler, classical formulation. Both Laub and Einstein discounted the spacetime formalism as too complicated. However, it turned out that Minkowski's spacetime formalism was fundamental for the further development of special relativity" (Wikipedia). Pais, *Subtle is the Lord,* pp. 151, 154. Shields 23. Weil 23. 43217

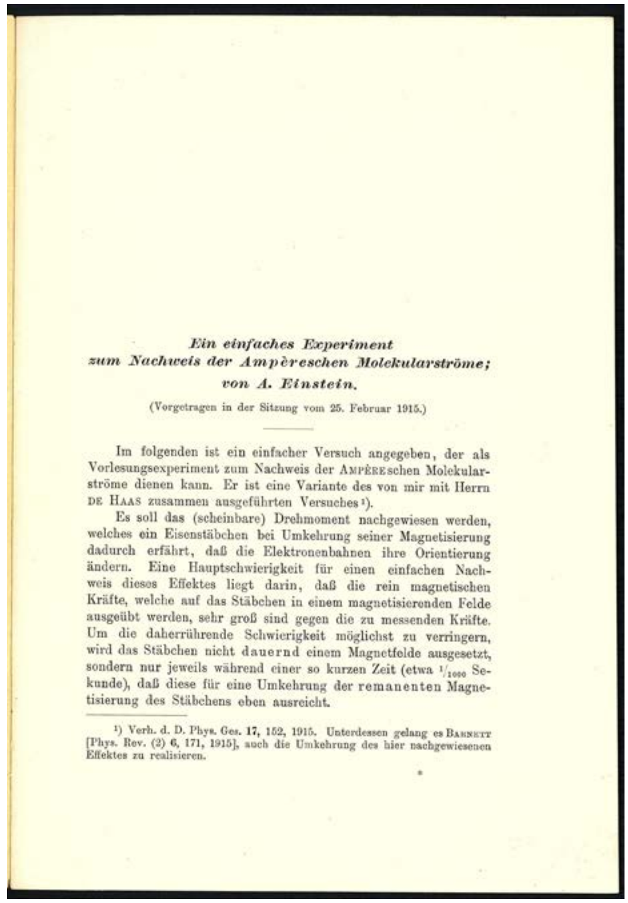
**48. Einstein, Albert** (1879-1955) and **Marcel Grossman** (1878-1936). Entwurf einer verallgemeinerten Relativitätstheorie und einer Theorie der Gravitation. 38pp. Leipzig & Berlin: Teubner, 1913. 254 x 170 mm. Original printed wrappers, chipped. Library stamps. Very good. $2750

**First Separate Edition**. "After his first discussions with Grossmann, Einstein had found the correct starting point for general relativity. The real work could now begin . . . The Einstein-Grossmann paper, published in 1913, contains profound physical insight into the nature of measurement, some correct general relativistic equations, some faulty reasoning, and clumsy notation" (Pais, *Subtle is the Lord*, p. 216). Weil, *Albert Einstein Bibliography*, *58. 43305

**49. Einstein, Albert** (1879-1955) and **Wander Johann de Haas** (1878-1960). Notiz zu unserer Arbeit "Experimenteller Nachweis der Ampèreschen Molekularströme." Offprint from *Verhandlungen der Deutschen Physikalischen Gesellschaft* 17 (1915). 1 sheet (p. 420). 228 x 156 mm. Original printed wrappers. Fine copy. $2750

**First Edition, Offprint Issue.** In 1915 Einstein and Dutch physicist Wander Johannes de Haas conducted gyromagnetic experiments leading to the discovery of the Einstein-de Haas effect, which corresponds to the mechanical rotation induced in a ferromagnetic cylinder suspended inside a coil when an impulse of electric current is sent through the coil. Einstein was very enthusiastic about the experimental results, stating that he and de Haas had "given firm proof of the existence of Ampère's molecular currents" (quoted in Pais, *Subtle is the Lord,* pp. 245-246). Einstein and de Haas published their results in a paper published earlier in 1915 (see Weil *73); the present "Notiz" is a response to a communication from American physicist Samuel Jackson Barnett, who had begun performing similar experiments in 1909 and obtained results complementing those of Einstein and de Haas. Weil, *Albert Einstein Bibliography,* *73(n). 43295

**50. Einstein, Albert** (1879-1955). Ein einfaches Experiment zum Nachweis der Ampèreschen Molekularströme. Offprint from *Verhandlung der Deutschen Physikalischen Gesellschaft* 18 (1916). 173-177pp. 230 x 157 mm. Original printed wrappers. Fine copy. $7500



*Ein einfaches Experiment zum Nachweis der Ampèreschen Molekularströme; von A. Einstein.*

(Vorgetragen in der Sitzung vom 25. Februar 1915.)

Im folgenden ist ein einfacher Versuch angegeben, der als Vorlesungsexperiment zum Nachweis der Ampèreschen Molekularströme dienen kann. Er ist eine Variante des von mir mit Herrn de Haas zusammen ausgeführten Versuches [1]).

Es soll das (scheinbare) Drehmoment nachgewiesen werden, welches ein Eisenstäbchen bei Umkehrung seiner Magnetisierung dadurch erfährt, daß die Elektronenbahnen ihre Orientierung ändern. Eine Hauptschwierigkeit für einen einfachen Nachweis dieses Effektes liegt darin, daß die rein magnetischen Kräfte, welche auf das Stäbchen in einem magnetisierenden Felde ausgeübt werden, sehr groß sind gegen die zu messenden Kräfte. Um die daherrührende Schwierigkeit möglichst zu verringern, wird das Stäbchen nicht dauernd einem Magnetfelde ausgesetzt, sondern nur jeweils während einer so kurzen Zeit (etwa $^1/_{1000}$ Sekunde), daß diese für eine Umkehrung der remanenten Magnetisierung des Stäbchens eben ausreicht.

[1]) Verh. d. D. Phys. Ges. **17**, 152, 1915. Unterdessen gelang es Barnett [Phys. Rev. (2) **6**, 171, 1915], auch die Umkehrung des hier nachgewiesenen Effektes zu realisieren.

**First Edition, Offprint Issue.** In 1915 Einstein and Dutch physicist Wander Johannes de Haas conducted gyromagnetic experiments leading to the discovery of the Einstein-de Haas effect, which corresponds to the mechanical rotation induced in a ferromagnetic cylinder suspended inside a coil when an impulse of electric current is sent through the coil. Einstein was very enthusiastic about the experimental results, stating that he and de Haas had "given firm proof of the existence of Ampère's molecular currents" (quoted in Pais, *Subtle is the Lord*, pp. 245-246). After his collaboration with de Haas ended, Einstein published the present paper on the Einstein-de Haas effect, proposing a new experimental method for determining gyromagnetism. The Einstein-de Haas effect is now known to reveal a relationship between magnetism, angular momentum and electron spin; however, this was not understood at the time, as electron spin was not discovered until the 1920s. Weil, *Albert Einstein Bibliography*, 82. 43294

**51. Einstein, Albert** (1879-1955). Aether und Relativitätstheorie. 15pp. Berlin: Springer, 1920. 221 x 146 mm. Original printed wrappers, foxed. Minor internal foxing but very good. $750

**First Edition?** (cover title does not include the date Einstein delivered his lecture; see Weil). "By royal decree of June 24, 1920, a special chair in Leiden [University] was created for [Einstein], enabling him to come to that university for short periods of his choosing. On October 27, 1920, Einstein began his new position with an inaugural address on aether and relativity theory" (Pais, *Subtle is the Lord*, p. 313). Weil, *Albert Einstein Bibliography*, 111. 43308

**52. Einstein, Albert** (1879-1955). Eine Einfache Anwendung des Newtonschen Gravitationsgesetze auf die kugelförminge Sternhaufen. Offprint from *Der Festschrift der Kaiser Wilhelm Gesellschaft zur Förderung der Wissenschaften zu ihrem 10jährigen Jubiläum* (Berlin: Julius Springer, 1921). 50-52pp. 260 x 175 mm. Original printed wrappers, a little chipped. Very good. $500

**First Separate Edition**. On a simple application of Newton's law of gravitation to spherical star clusters. Weil, *Albert Einstein Bibliography*, 117. 43307

**53. Einstein, Albert** (1879-1955). Über ein den Elementarprozeß der Lichtemission betreffendes Experiment. Offprint from *Sitzungsberichte der preussischen Akademie der Wissenschaften* (1921). Single sheet (pp. 882-883). 256 x 184 mm. Minor marginal tears, one corner chipped, but very good. $750

**First Edition, Offprint Issue.** "Since, after 1917, Einstein firmly believed that light-quanta were here to stay, it is not surprising that he would look for new ways in which the existence of photons might lead to observable deviations from the classical picture. In this he did not succeed. At one point, in 1921, he thought he had found a new quantum criterion [published in the present paper], but it soon turned out to be a false lead" (Pais, *Subtle is the Lord*, pp. 412-413). Weil, *Albert Einstein Bibliography*, 118. 43316

**54. Einstein, Albert** (1879-1955) and **Paul Ehrenfest** (1880-1933). Quantentheoretische Bemerkungen zum Experiment von Stern und Gerlach. Offprint from *Zeitschrift* für *Physik* 11 (1922). 31-34pp. 229 x 155 mm. Original printed self-wrappers. Light toning but fine otherwise. $2750

**First Edition, Offprint Issue.** In 1922 the physicists Otto Stern and Walther Gerlach conducted a now-classic experiment in which a beam of silver atoms was streamed through an inharmonious magnetic field in order to observe the atoms' deflection patterns. Rather than a random and continuous distribution, as predicted by classical theory, the atoms passing through the field were deflected up or down by a specific amount, demonstrating that they had intrinsically quantum properties. The Stern-Gerlach experiment corroborated the Bohr-Sommerfeld model of the atom and strongly influenced later developments in 20th century physics. However, the experiment also created some serious difficulties for quantum physicists in the period before the rise of the "new" quantum mechanics.

Einstein and Ehrenfest addressed one of these difficulties—connected with space quantization—in their joint paper, in which

> they dealt in particular with the problem of how the orbits of the atom would obtain their discrete directions which they exhibit while passing through the inhomogeneous magnetic field. Under the assumption that the mechanism causing the orientation was provided by the interaction with the radiation field, Einstein and Ehrenfest estimated that for a field strength of 10,000 G a change in the direction of the orbit would take place in roughly $10^{11}$ s; this long time interval would be reduced in the presence of heat radiation at room temperature . . . to about $10^{9}$ s. How could, they asked, the experimental situation be explained, which implied that the discrete orientations of the orbits in silver atoms were obtained in less than $10^{-4}$ s. In order to deal with this evident puzzle, Einstein and Ehrenfest proposed two alternatives: first, that the silver atoms were always in the states of spatial quantization; second, the orientations of the electron orbits arose from an interaction of the atoms with the radiation field, which involved much smaller reaction times . . . However, they found that both alternatives created considerable difficulties in the understanding of the atomic processes . . . Thus Einstein and Ehrenfest concluded: "The difficulties mentioned above show how unsatisfactory are both interpretations of the results found by Stern and Gerlach" (Mehra & Rechenberg, *The Historical Development of Quantum Theory* 2, pp. 443-444).

Pais, *Subtle is the Lord,* p. 328. Weil, *Albert Einstein Bibliography,* 121. 43287

**55. Einstein, Albert** (1879-1955) and **Paul Ehrenfest** (1880-1933). Zur Quantentheorie des Strahlungsgleichgewichts. Offprint from *Zeitschrift* für *Physik* 19 (1923). 301-306pp. Original printed self-wrappers. 230 x 157 mm. Light toning but very good. $1500

**First Edition, Offprint Issue.** In 1916, after publishing his great work on general relativity, Einstein returned to the question of blackbody radiation. In November 1916 he wrote to his friend Besso that "a splendid light has dawned on me about the absorption and emission of radiation" (quoted in Pais, p. 405), one that led him to a new derivation of Planck's radiation law and convinced him of the reality of light-quanta (photons). After publishing these results in three papers, culminating with the famous "Zur Quantentheorie der Strahlung" (1917), Einstein kept looking for "new ways in which the existence of photons might lead to observable derivations from the classical picture" (Pais, p. 413). He found none until 1923, when Arthur Compton and Peter Debye independently derived the relativistic kinematics for the scattering of a photon off an electron at rest. The work of Compton and Debye led Wolfgang Pauli to extend Einstein's work of 1917 to the case of radiation in equilibrium with free electrons (see Pais, p. 414*n*). "Pauli examined the requirements of detailed balance under Lorentz transformations and found that scattering of light by free electrons must include a term of a form which we would now call stimulated emission . . . Einstein and Ehrenfest then showed that Pauli's results could be obtained by an extension of [Einstein's] 1917 paper with the unnecessary specialization to discrete energy levels removed . . . The core of Einstein's argument is that the scattering process should be broken into two parts: the absorption of energy from radiation of frequency $\nu_1$ and the emission of energy as radiation of frequency $\nu_2$" (Lewis, p. 42). Lewis, "Einstein's derivation of Planck's radiation law," *American Journal of Physics* 41 (1973): 38-44. Pais, *Subtle is the Lord,* ch. 21. Weil, *Albert Einstein Bibliography,* 138. 43288

**56. Einstein, Albert** (1879-1955). Notiz zu der Arbeit von A. Friedmann "Über die Krümmung des Raumes." Offprint from *Zeitschrift für Physik* 16 (1923). Single sheet, unpaginated. 230 x 155 mm. One corner creased but very good. $750

**First Edition, Offprint Issue.** Einstein's second response to Friedmann's groundbreaking paper on equations governing the expansion of space, which made a valuable contribution to Einstein's theory of relativity and admitted the possibility of an expanding universe. Einstein at first believed that Friedmann's reasoning was incorrect, then corrected his own objection in the present brief "Notiz" and called Friedmann's results "clarifying." Pais, *Subtle is the Lord*, p. 288. Weil, *Albert Einstein Bibliography*, 130. 43318

**57. Einstein, Albert** (1879-1955). Bietet die Feldtheorie Möglichkeiten für die Lösung des Quantenproblems? Offprint from *Sitzungsberichte der preussischen Akademie der Wissenschaften* (1923). 359-364pp. 254 x 184 mm. Original printed wrappers. Very good. $500

**First Edition, Offprint Issue**. On whether field theory offers possibilities for solving the problems with the old quantum theory. Weil, *Albert Einstein Bibliography*, 137. 43315

**58. Einstein, Albert** (1879-1955). Allgemeine Relativitätstheorie und Bewegungsgesetz. Offprint from *Sitzungsberichte der preussischen Akademie der Wissenschaften* (1927). 235-245pp. 255 x 183 mm. Original printed wrappers. Fine. $450

**First Edition, Offprint Issue.** On the problem of motion in general relativity theory; a follow-up to his and Grommer's paper of the same title published earlier in 1927. Weil, *Albert Einstein Bibliography*, 160. 43303

**59. Einstein, Albert** (1879-1955). Théorie unitaire du champ physique. In *Annales de l'Institut Henri Poincaré* 1, fasc. 1 (1930): 1-24. [With:] **Fermi, Enrico** (1901-54). La théorie du rayonnement. In *ibid.*: 25-52. Whole number. [2], 74, [2]pp. 285 x 197 mm. (uncut and unopened). Original printed wrappers, a bit sunned, lower corner of front wrapper chipped and creased. Very good. $750

**First Edition.** This issue of the *Annales de l'Institut Henri Poincaré* contains the texts of Einstein's lecture on unified field theory and Fermi's lecture on the theory of radiation, both delivered at the Institut in 1929. Weil, *Albert Einstein Bibliography,* 174. Not in Fermi, *Collected Papers.* 51013

**60. Einstein, Albert** (1879-1955). Zur Theorie der Raüme mit Riemann-Metrik und Fermparallelismus. Offprint from *Sitzungsberichte der preussischen Akademie der Wissenschaften* (1930). Single sheet (pp. 1-2). 256 x 184 mm. Upper edge a bit creased, light toning, but very good. $600

**First Edition, Offprint Issue.** One of Einstein's last papers on Riemann metrics and distant parallelism, written the year before he abandoned this approach to constructing a unified field theory. Pais, *Subtle is the Lord*, p. 347. Weil, *Albert Einstein Bibliography*, 173. 43314

**61. Einstein, Albert** (1879-1955). Auf die Riemann-Metrik und den Fern-Parallismus gegründete einheitliche Feldtheorie. Offprint from *Mathematische Annalen* 102 (1930). 685-697pp. Original printed self-wrappers. 233 x 157 mm. Very good apart from small split in lower spine. $750

**First Edition, Offprint Issue.** Weil, *Albert Einstein Bibliography*, 171. 43306

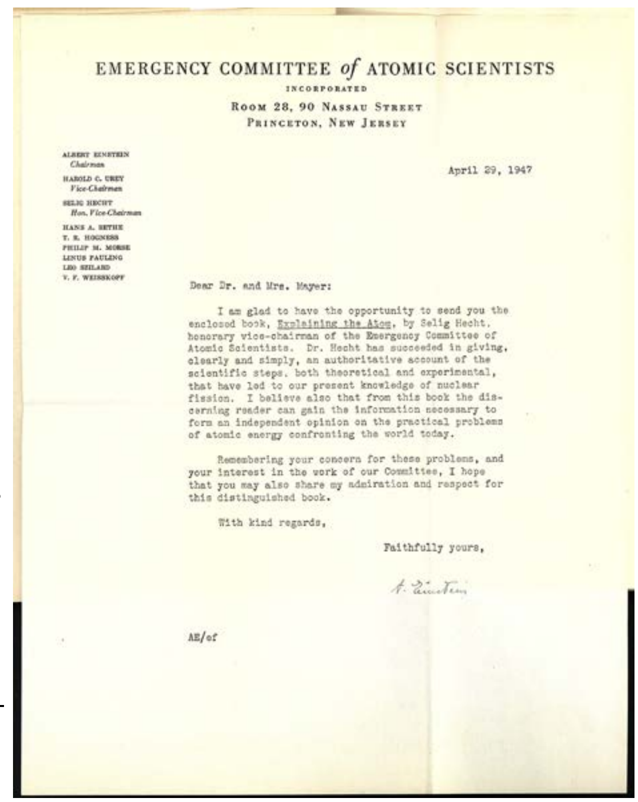
**62. Einstein, Albert** (1879-1955) and **Walther Mayer.** Semi-vektoren und Spinoren. Offprint from *Sitzungsberichte der Preussischen Akademie der Wissenschaften* 32 (1932). 31pp. 256 x 183 mm. Original printed wrappers, a little chipped and darkened, small splits in spine. Very good. $600

**First Edition, Offprint Issue.** Einstein's work on semivectors "was stimulated by Ehrenfest's insistence on a better understanding of the relation between single-valued and double-valued representations of the Lorentz group . . . [Einstein and Mayer] went on to relate semivectors to the Dirac equation and to generalize the formalism to general relativity" (Pais, *Subtle is the Lord*, pp. 451-452). Weil, *Albert Einstein Bibliography*, 186. 43300

**63. Einstein, Albert** (1879-1955). Demonstration of the non-existence of gravitational fields with a non-vanishing total mass free of singularities. Offprint from *Universidad Nacional de Tucuman Revista*, Serie A, 2 (1941). 11-15pp. 270 x 179 mm. Original printed wrappers. Very good. $500

**First Edition, Offprint Issue.** "Address to joint meeting of the American Physics Society and the American Association of Physics Teachers, Princeton, Dec. 29, 1941, under the title: 'Solutions of finite mass of the gravitational equations'" (Weil). Weil, *Albert Einstein Bibliography*, 208. 43311

**64. Einstein, Albert** (1879-1955). Reproduced typescript form letter with autograph signature, on letterhead of the Emergency Committee of Atomic Scientists, addressed to Dr. and Mrs. Mayer (recipients' names in original typescript). 1 page. Princeton, NJ, 29 April 1947. 279 x 215 mm. Creased where folded but very good. Tipped into: **Hecht, Selig** (1892-1947). Explaining the atom. xiii, 205pp. Text illustrations. 210 x 142 mm. Original cloth, sunned, spine faded, chip in lower spine, extremities a bit worn, small portions cut from margins of pp. xi-xvi; in very good dust-jacket. $4500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April 29, 1947

Dear Dr. and Mrs. Mayer:

I am glad to have the opportunity to send you the enclosed book, Explaining the Atom, by Selig Hecht, honorary vice-chairman of the Emergency Committee of Atomic Scientists. Dr. Hecht has succeeded in giving, clearly and simply, an authoritative account of the scientific steps, both theoretical and experimental, that have led to our present knowledge of nuclear fission. I believe also that from this book the discerning reader can gain the information necessary to form an independent opinion on the practical problems of atomic energy confronting the world today.

Remembering your concern for these problems, and your interest in the work of our Committee, I hope that you may also share my admiration and respect for this distinguished book.

With kind regards,

Faithfully yours,

A. Einstein

AE/ef

Einstein's letter, written in his capacity as chairman of the Emergency Committee of Atomic Scientists, promotes Hecht's book on atomic energy, described as "by all odds the best book on atomic energy so far to be published for the ordinary reader" (quoted in the Wikipedia article on Hecht). The letter reads in part:

> I am glad to have the opportunity to send you the enclosed book, *Explaining the Atom*, by Selig Hecht, honorary vice-chairman of the Emergency Committee of Atomic Scientists. Dr. Hecht has succeeded in giving, clearly and simply, au authoritative account of the scientific steps, both theoretical and experimental, that have led to our present knowledge of nuclear fission. I believe also from this book the discerning reader can gain the information necessary to form an independent opinion on the practical problems of atomic energy confronting the world today . . .

The letter is tipped into a copy of the first edition of Hecht's book. 51022

**65. Epstein, Paul Sophus** (1883-1966). The Stark effect from the point of view of Schroedinger's quantum theory. Offprint from *Physical Review* 28 (1926). 695-710pp. 255 x 180 mm. Original printed wrappers, margins a bit faded. Very good. $750

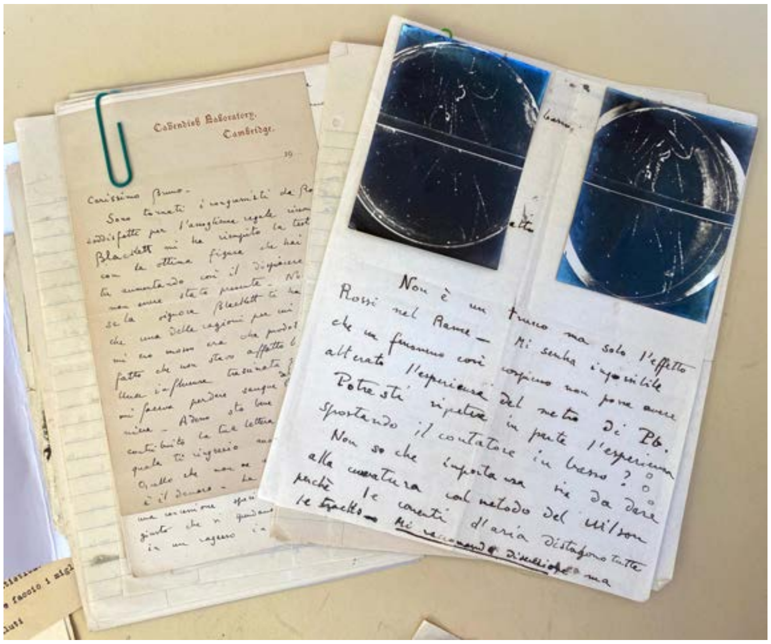
**First Edition, Offprint Issue.** In 1916 Epstein, a Russian-American physicist, had been the first to give a correct theoretical prediction of the Stark effect in atomic hydrogen using the old Bohr-Sommerfeld quantum theory. Ten years later, after the introduction of Schrödinger's wave mechanics, Epstein used Schrödinger's theory of the Stark effect to "reproduce quickly the first- and second-order Stark effects in wave mechanics" (Mehra & Rechenberg, *The Historical Development of Quantum Theory*, 5, p. 721). 51000

*Extraordinary Scientific Archive Featuring Four Letters from Fermi*

**66. Fermi, Enrico** (1901-54) *et al*. Archive of scientific correspondence to **Bruno Rossi** (1905-93) plus related materials, as listed below. 68 items total. 1930-36. Various sizes. Rust-stains from paper clips on some items, a few minor chips and marginal tears, but very good. For a complete calendar of the items in this collection, click here. $37,500

An extraordinary archive of scientific correspondence, featuring four letters from **Enrico Fermi**, written to Italian experimental physicist Bruno Rossi, one of the founders of the study of cosmic rays and a major contributor to particle physics. The archive also includes correspondence from Nobel laureates **Hans Bethe**, **Patrick Blackett**, **John D. Cockcroft,** and **Emilio Segrè**, as well as letters from **Lise Meitner**, **Hans Geiger**, **Homi J. Bhabha**, **Yoshio Nichina**, and Rossi's student **Giuseppe Occhialini**. The materials in the archive date from the period 1930 to 1936, the time when Rossi did some of his most important and fruitful work on cosmic radiation.

As a young physics professor at the University of Florence, Rossi read Walther Bothe and Werner Kolhörster's 1929 paper announcing the existence of charged cosmic ray particles that could penetrate gold by more than four centimeters—far more than any other form of radiation known at the time. Inspired by this astonishing discovery, Rossi decided to devote his career to studying cosmic radiation. In 1930, using triode vacuum tubes, Rossi invented an electronic coincidence circuit for detecting charged cosmic particles, a vast improvement over the cumbersome apparatus used by Bothe. Rossi and his student Giuseppe Occhialini used the new device, in conjunction with the improved Geiger-Müller particle detector, to confirm Bothe's investigations and to perform important new research.




In 1930, Bruno Rossi used electronic valves to register coincident pulses from the Geiger counters. He arranged the detectors in a triangle so that the cosmic rays could not transverse all three counters. In 1932 he found that 60% of the cosmic rays that pass through the 25 cm piece of lead could also traverse a full metre of lead. This was the first demonstration of the production of showers of secondary particles. Rossi also demonstrated that the cosmic ray flux contains a soft component easily absorbed in a few millimeters of lead and a hard component of charged particles with energies above 1 GeV. This ended Millikan's theory that the cosmic rays consisted of gamma rays.

Rossi demonstrated that the Earth's magnetic field bends incoming charged particle showers so that if they are more negative, more come from the east than from the west and vice-versa. In 1933, Rossi and others demonstrated an east-west effect that showed that the majority of cosmic rays were positive ("CERN Accelerating Science." *Bruno Rossi: Cosmic Rays Are Positive Charged Particles*, CERN [web]).

The most illustrious of the physicists represented in the Rossi archive is **Enrico Fermi**, who received the Nobel Prize in 1938 for his work on induced radioactivity by neutron bombardment, and four years later built the world's first man-made nuclear reactor, which made possible the development of the atomic bomb. The earliest of the Fermi letters in this collection, dated 7 July 1931, deals with Rossi's cosmic ray research (all translations ours):

> ". . . I am pleased to hear that the indications that penetrating radiation has a positive charge seem to be confirmed; of course, a very careful search for possible systematic errors should still be made; and possibly try to mechanize as much as possible the operations of variations in the counters' potential, to which one could attribute the causes of a consistency a bit greater than the purely statistical . . .

Fermi's postcard of 30 October 1932, together with the telegram dated the following day, congratulated Rossi for being one of three winners of the science competition sponsored by the University of Ferrara, in which Fermi was one of the judges:

> I am pleased to inform you that the Ferrara competition, which was virtually decided yesterday evening, had a favorable outcome for you, who came in second, having had two votes for first place . . . On the other hand, Segrè, who in my opinion should have also gotten in, was left out . . .

In his letter of 8 July 1934, Fermi responded to Rossi's request for suitable theoretical physicists to fill positions at the University of Padua's new Physics Institute, which Rossi was overseeing:

> . . . As far as being asked about a theoretical physicist, I don't know what to answer. In my opinion the best that are currently on the marked are [Gian Carlo] Wick and [Giulio] Racah; but I wouldn't believe they want to move from where they are, although I haven't been able to ask them about it . . . Ettore Majorana, whom I always consider to have very exceptional attitudes, has been in poor health this year . . . Among the very best perhaps the best of those I know is Eugenio Fubini . . .

The fourth Fermi letter, dated 20 February 1935, refers to a paper by Rossi and Giulia Alocco, as well as an experiment by physicist Wilhelm Lenz and Fermi's own work on slow neutrons:

> . . . The experiment described by Lenz seemed to me from the beginning to be rather strange, and it did not surprise me very much that you found a different result.
>
> We are collecting the latest results on neutron radioactivity, but this topic is also gradually being exhausted. We will have to look for something new!

Another highlight of the Rossi archive is a series of 13 detailed scientific letters (some illustrated with photographs or drawings) from his first graduate student, **Giuseppe Occhialini** (1907-93), describing the research Occhialini was doing under Patrick Blackett at Cambridge University's Cavendish Laboratory. Occhialini spent three years (1931-34) at the Cavendish, during which he performed important work on cloud chambers and cosmic radiation; in 1932, under Blackett's leadership, Occhialini collaborated in the discovery of the positron in cosmic rays. Occhialini was an important protagonist in the use of photographic methods to study nuclear processes, most notably in 1946 when he collaborated with Cecil Frank Powell and César Lattes in the discovery of the pion. 45179

**67. Fermi, Enrico** (1901-1954). (1) Sul calcolo degli spettri degli ioni. Offprint from *Memorie della Reale Accademia d' Italia: Classe di scienze fisiche matematiche e naturali* 1, Fisica no. 2 (1930). (2) L'effeto Raman nelle molecole e nei cristalli. Offprint from *ibid*., Fisica no. 3 (1932). Together 2 offprints. Rome: Reale Accademia d' Italia, 1930-32. 251 x 179 mm. (unopened). Original gray printed wrappers, sunned, wrappers of (2) splitting at spine. Some toning, but very good. $850

**First Separate Editions.** Between 1930 and 1934 Fermi published a series of five papers describing his investigations of the theory of the hyperfine structure of spectral lines (first proposed by Pauli in 1923) and the nuclear magnetic momenta; we are offering two of these papers here. Fermi's investigations culminated in his explanations of beta decay and the introduction of the Fermi constant. Fermi received the Nobel Prize in 1938 for his work on induced radioactivity by neutron bombardment and his discovery of transuranic elements. Fermi, *Collscted Papers,* ed. Segrè, 63, 71. Norman 780-781. 44349

**68. Fermi, Enrico** (1901-54) and **George Uhlenbeck** (1900-1988). On the recombination of electrons and positrons. Offprint from *Physical Review* 44 (1933). 2pp. 268 x 201 mm. Single sheet, unbound. Some marginal fraying especially at right, some soiling, horizontal crease, a few small marginal tears. Good copy. From the library of physicist Walther Gerlach (1889-1979), with his initials in pencil on the first page, Fermi's and Uhlenbeck's names in Gerlach's hand on the first page. Docketed. $3750

**First Edition, Rare Offprint Issue.** "The discovery of the positron [by Carl Anderson in 1932] and above all the processes of creating and destructing pairs of electrons and positrons, raised great interest around the world. Fermi too tackled the subject from the theoretical point of view. In a study with Uhlenbeck, carried out during his stay in August 1933 at the University of Michigan, he worked on the process of annihilation of an electron and a positron. In particular he tried to confirm whether a certain spectral line, identified by Louis H. Gray and Gerald T. P. Tarrant in the 'scattering of hard γ rays', could be attributed, as Blackett and Occhialini had suggested, to an annihilation process but he found that, on the basis of Dirac's theory, it did not seem possible" (F. Guerra and N. Robotti, *The Lost Notebook of Enrico Fermi,* p. 75).

Fermi and Uhlenbeck's paper was published in both English and Italian; the English version is the one included in Fermi's *Collected Papers.* This copy is from the library of Walther Gerlach, co-discoverer of the Stern-Gerlach effect (spin quantization in a magnetic field). Fermi, *Collected Papers,* no. 77b. 46143

## *Goudsmit's Copy*

**69.** [**Fermi, Enrico** (1901-54).] **Beckerley, James G.** (1915-2006). Neutron physics: A revision of I. Halpern's notes on E. Fermi's lectures in 1945. ii, 96pp. Text illustrations. 267 x 201 mm. Oak Ridge, TN: United States Atomic Energy Commission, Technical Information Branch, n.d. [1949]. Original printed wrappers, stapled, light soiling, front wrapper chipped, spine partially defective. Very good. From the library of Samuel Goudsmit (1902-78), with his stamp and name in pencil on the front wrapper; bookplate of the American Institute of Physics's Niels Bohr Library stating that this is Goudsmit's copy. $950

**First Edition.** "In the Fall of 1945 a course on Neutron Physics was given by Professor Fermi as part of the program of the Los Alamos University . . . The present revision is based on class notes prepared by I. Halpern with some assistance by B. T. Feld and issued first as document LADC 255 and later with wider circulation as MDDC 320. Having found the document most useful in teaching an introductory course in nuclear physics, the author of the present revision felt that the material should be made more widely available . . . To this end the notes issued as MDDC 320 have been revised and made available in this form for wiser distribution" (p. i). Beckerley, an American nuclear physicist, was the director of classification at the U.S. Atomic Energy Commission.

This copy is from the library of Samuel Goudsmit, co-discoverer of electron spin. 50999

**70. Feynman, Richard** (1918-88). A relativistic cut-off for classical electrodynamics. Offprint from *The Physical Review* 74 (1948). 939-946pp. 265 x 202 mm. Without wrappers as issued. Upper corners and last leaf professionally repaired with loss of four letters on the last leaf (not affecting legibility), last leaf a bit soiled, fore-edges a little frayed. Good copy. $7500

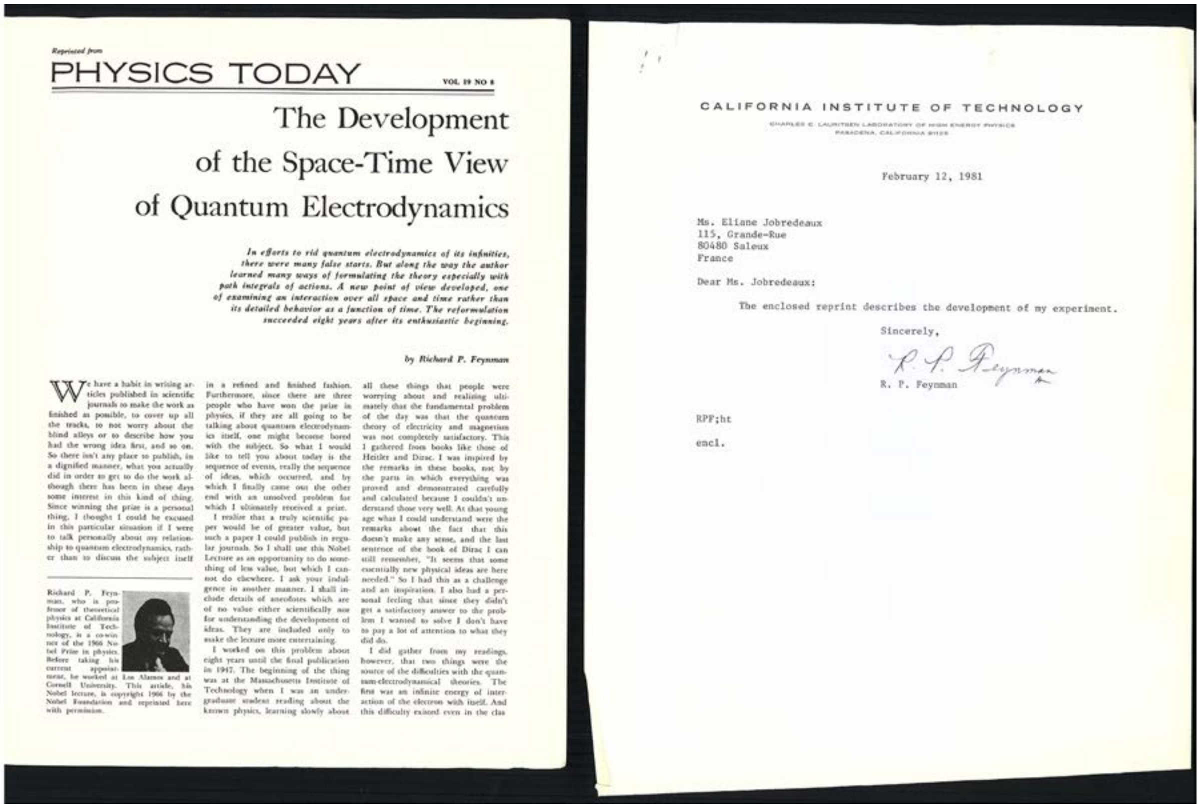
**First Edition, Offprint Issue** of Feynman's paper proposing a modification of classical electrodynamics to a form suitable for quantization. Feynman received the Nobel Prize for physics in 1965 (sharing it with Shinichiro Tomonaga and Julian Schwinger) for his fundamental work in quantum electrodynamics.

In the spring of 1948, prior to publishing any of his work on quantum electrodynamics, Feynman was invited to give a talk at the Pocono Conference on the problems of fundamental physics, which afforded him the first opportunity to present his ideas on QED to an audience of fellow physicists. By this time "Feynman had reworked almost all of quantum electrodynamics by his new technique of space-time diagrams. He had reached the most important part of his new results: namely, the relativistic formulation of quantum electrodynamics and, especially, perturbation theory, the relativistic cutoff and the renormalization of mass, closed expressions for the transition of amplitude and causal propagators, a new operator calculus . . . However, before the Pocono Conference, Feynman had not published anything on quantum electrodynamics and he did not have the mathematical proofs of all his results" (Mehra & Rechenberg, 6, p. 1051).

Unsurprisingly, Feynman's unorthodox approach to QED baffled the attendees of the Pocono Conference, which included such titans of quantum physics as Niels Bohr and Paul Dirac. Feynman had such difficulty explaining his ideas that, as he recalled later "I said to myself, I'll just have to write it all down and publish it, so that they can read it and study it, because I know it's right!" (quoted in Mehra & Rechenberg, 6, p. 1057). In June 1948 Feynman published the present paper, which "dealt largely with the action-at-a-distance formulation he had worked on before getting involved with the war effort, but now with a density of field quanta playing the role of a regulator, so that the energy of a particle was made finite" (Mehra & Rechenberg, 6, p. 1092). Ezhela et al., *Particle Physics: One Hundred Years of Discoveries,* pp. 99-100. Mehra & Rechenberg, *Historical Development of Quantum Theory,* 6, pp. 1051-1093. 50966

**71. Feynman, Richard** (1918-88). A relativistic cut-off for classical electrodynamics. In *The Physical Review* 74 (1948): 939-94. Whole number. 851-990pp. 267 x 197 mm. Original printed wrappers. Fine. $1500

**First Edition,** journal issue. 46173



Reprinted from

PHYSICS TODAY VOL. 19 NO. 8

The Development of the Space-Time View of Quantum Electrodynamics

*In efforts to rid quantum electrodynamics of its infinities, there were many false starts. But along the way the author learned many ways of formulating the theory especially with path integrals of actions. A new point of view developed, one of examining an interaction over all space and time rather than its detailed behavior as a function of time. The reformulation succeeded eight years after its enthusiastic beginning.*

by Richard P. Feynman

CALIFORNIA INSTITUTE OF TECHNOLOGY

February 12, 1981

Ms. Eliane Jobredeaux
115, Grande-Rue
80480 Saleux
France

Dear Ms. Jobredeaux:

The enclosed reprint describes the development of my experiment.

Sincerely,

R. P. Feynman

R. P. Feynman

RPF;ht

encl.

**72. Feynman, Richard** (1918-88). (1) The development of the space-time view of quantum electrodynamics. Offprint from *Physics Today* 19 (1966). [11]pp. Light creasing. (2) Typed letter to Eliane Jobredeaux on California Institute of Technology letterhead, signed "R. P. Feynman" in a secretarial hand, with cover. 1 sheet. Pasadena, CA, 12 February 1981. 270 x 218 mm. Light creasing, faint rust-mark from paperclip. Together 2 items. Very good. $3750

The rare offprint of Feynman's Nobel lecture presented by Feynman 15 years after he received the Nobel Prize. This is the first instance that we can recall in which an offprint by Feynman is accompanied by his original presentation letter. Also, we learn from this letter than Feynman used a secretary to send and sign letters like this which presumably he dictated. Another detail evident from this letter is that Feynman retained copies of this offprint as many as 15 years after it was published. His letter reads, "The enclosed reprint describes the development of my experiment. Sincerely, R. P. Feynman." Feynman enclosed a reprint of his entertaining Nobel lecture, which departed from usual practice in presenting an informal anecdotal account of his discovery, rather than a rigorously scientific presentation which he feared might bore his listeners. Magill, ed., *The Nobel Prize Winners: Physics*, pp. 903-10. 50226

**73. Fokker, Adriaan Daniel** (1887-1972). The virtual displacement of the electro-magnetic and of the gravitational field in applications of Hamilton's variation principle. Offprint from Koninklijke Akademie van Wetenschappen te Amsterdam, *Proceedings* 19 (1917). 17pp. 266 x 182 mm. Original printed wrappers, sunned, light spotting. Very good. *Presentation Copy,* inscribed to **Niels Bohr** (1885-1962) on the front wrapper: "Dr. N. Bohr with the author's compliments." $1750

**First Edition in English, Offprint Issue** (a Dutch version appeared the same year). The Dutch physicist Adriaan Fokker, a student of Lorentz, made several contributions to both special and general relativity, collaborating with Einstein in 1914 on a paper on Nordström's theory of gravitation and publishing a summary of the Einstein-Grossmann theory of gravitation the following year. The present paper, Fokker's first on general relativity since the Einstein-Grossmann paper, "gave a reformulation and an extension of earlier work by Lorentz on the Hamiltonian formulation of general relativity. Notable in this paper was a derivation of the contracted Bianchi identities (as a consequence of the variational principle) and a discussion of its implications for the field equations" (Kox, p. 42).

Fokker presented this copy to Niels Bohr, winner of the Nobel Prize for physics in 1922 for his fundamental contributions to our understanding of atomic structure and quantum theory. A. Kox, "General relativity in the Netherlands," J. Eisenstadt and A. J. Kox, eds., *Studies in the History of General Relativity*, pp. 39-56. 46115

**74. Frisch, Otto Robert** (1904-79); **Hans von Halban** (1908-64); and **Jørgen Koch** (1909-71). Some experiments on the magnetic properties of free neutrons. Offprint from *Physical Review* 53 (1938). 719-726pp. 267 x 201 mm. Without wrappers as issued. Creased horizontally, edges frayed, a few marginal tears. Good copy. $850

**First Edition, Offprint Issue.** "From the experiments it is concluded that the neutron has a magnetic moment not far from 2 x 1/1840 Bohr magneton and that the sign is negative" (p. 719). Frisch is best known as the co-discoverer, with Lise Meitner, of nuclear fission. 51011

**75. Gell-Mann, Murray** (1929-2019) and **Kenneth M. Watson** (1921- ). The interactions between pi-mesons and nucleons. Offprint from *Annual Review of Nuclear Science* 4 (1954). 219-270pp. 219 x 151 mm. Original printed wrappers. Fine. From the library of Nobel laureate Owen Chamberlain (1920-2006), with his signature on the front wrapper. Very good. $500

**First Edition, Offprint Issue.** Gell-Mann, the physicist who coined the term "quark," received the 1969 Nobel Prize in physics for his contributions and discoveries concerning the classification of elementary particles and their interactions. 43673

**76. Gell-Mann, Murray** (1929-2019) and **Fredrik Zachariasen** (1931-99). Form factors and vector mesons. Report CTSL-26. Reproduced typescript. [3], 41, [2, diagrams]ff. Errata sheet dated May 11, 1961 laid in. Pasadena: California Institute of Technology, 1961. 274 x 214 mm. Original printed wrappers. Errata sheet a bit frayed, but fine. From the library of Nobel Laureate Owen Chamberlain (1920-2006), with his stamp on the front wrapper. $1250

**Preprint Edition**, dated 14 April 1961; the journal version, published in *Physical Review,* appeared on 1 November. "Gell-Mann and Zachariasen were the first to treat the problem of vector-meson photon interaction and to find out the effective vector-meson-photon coupling constant on the basis of vector-meson dominance" (Zichichi, p. 308). A. Zichichi, "The basic $SU_3$ mixing: $\omega_8 \leftrightarrow \omega_1$," *Evolution of Particle Physics* (New York: Academic Press, 1970): 299-333. 43674

**77. Hahn, Otto** (1879-1968). Über die neuen Fällungs- und Adsorptionssätze und einige ihrer Ergebnisse. Offprint from *Die Naturwissenschaften* 14 (1926). 1196-1199pp. 271 x 196 mm. Without wrappers as issued. Creased horizontally, small marginal tears along crease, minor toning. Good to very good. From the library of Walther Gerlach (1889-1979), with his pencil signature on the first leaf. $500

**First Edition, Offprint Issue.** On new precipitation and adsorption sets and some of their results. This copy is from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). 50968

**78. Hahn, Otto** (1879-1968). Gesetzmäßigkeiten bei der Fällung und Adsorption kleiner Substanzmengen und ihre Beziehung zur radioaktiven Fällungsregel. Offprint from *Berichte der Deutschen Chemischen Gesellschaft* 59 (1926). 2014-2025pp. 234 x 157 mm. Original printed wrappers, slightly sunned. Very good. From the library of Walther Gerlach (1889-1979), with his pencil signature on the front wrapper. $500

**First Edition, Offprint Issue.** On regularities in the precipitation and adsorption of small amounts of substance and their relation to the radioactive precipitation rule. This copy is from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). 46014

**79. Hahn, Otto** (1879-1968). Das Protactinium als radioaktives und als chemisches Element. Offprint from *Die Naturwissenschaften* 16 (1928). 454-457pp. 271 x 196 mm. Without wrappers as issued. Creased horizontally, a few small marginal tears and creases, light soiling. Good to very good. $500

**First Edition, Offprint Issue.** In 1917 Hahn and Lise Meitner discovered the most stable isotope of element 91, which they named protactinium. The present paper, published eleven years later, discusses protactinium as a radioactive and as a chemical element. 46011

**80. Hahn, Otto** (1879-1968). Eine Methode zur Bestimmung der absoluten Grösse von Oberflächen. Offprint from *Annalen der Chimie* 462 (1928). 174-185pp. 218 x 145 mm. Original printed wrappers. Very good. $450

**First Edition, Offprint Issue.** On a method for determining the absolute size of surfaces. 50967

**81. Hahn, Otto** (1879-1968). Radioaktivität und chemische Elementarprozesse. Offprint from *Zeitschrift für Elektrochemie* (1932). 511-518pp. 287 x 203 mm. Without wrappers as issued. Some toning, light creasing, but very good. From the library of Walther Gerlach (1889-1979), with his initials in blue pencil on the first page. $450

**First Edition, Offprint Issue.** On radioactivity and elementary chemical processes. This copy is from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). 46012

**82. Hahn, Otto** (1879-1968) and **Lise Meitner** (1878-1968). Zur Entstehungsgeschichte der Bleiarten. Offprint from *Die Naturwissenschaften* 21 (1933). 1 page, on single unbound sheet. 270 x 197 mm. Creased horizontally, some marginal chipping and fraying. Good copy. From the library of Walther Gerlach (1889-1979), with his initials in blue pencil. $750

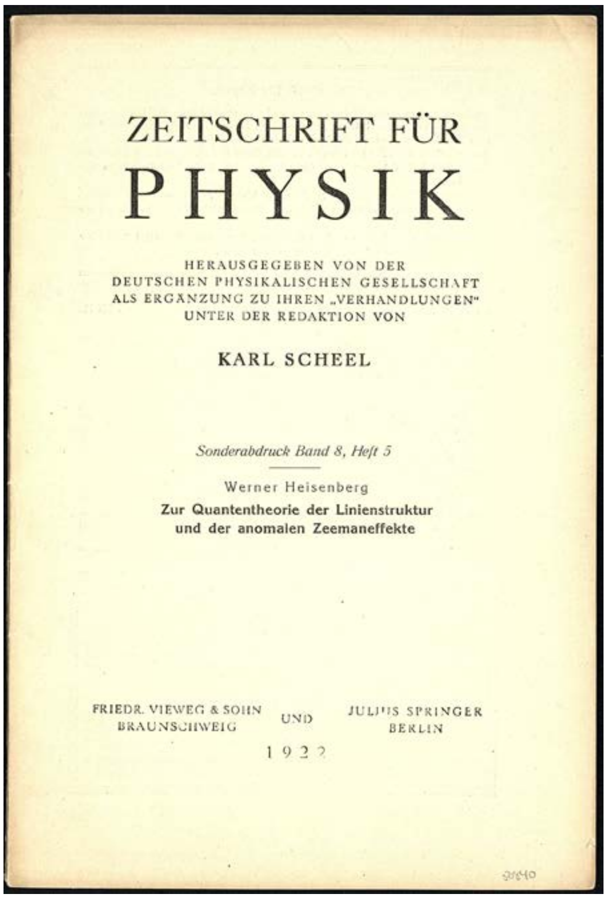
**First Edition, Offprint Issue.** On some isotopes of lead. Hahn and Meitner worked together in Berlin for thirty years, until she was forced to flee to Sweden 1n 1938 to escape the Nazis. This copy is from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). 46013

**83. Hahn, Otto** (1879-1968) and **Fritz Straßmann** (1902-80). (1) [with Hans Götte.] Einiges über die experimentelle Entwirrung der bei der Spaltung des Urans auftretenden Elemente und Atomarten. Offprint from *Abhandlungen der Preußischen Akademie der Wissenschaften, Math.-naturw. Klasse* (1942). 30pp. 297 x 211 mm. Original printed wrappers, a few chips, small splits in spine, a little toning and spotting. Stamp of the Staatsbibliothek Berlin on the front wrapper. (2) Die chemische Abscheidung der bei der Spaltung des Urans entstehenden Elemente und Atomarten (Allgemeiner Teil). Offprint from *Abhandlungen der Preußischen Akademie der Wissenschaften, Math.-naturw. Klasse* (1944). 14pp. 295 x 213 mm. Original printed wrappers, front wrapper with a few tiny chips. Together two items. Very good. $750

**First Editions, Offprint Issues.** Hahn and Straßmann are best known for the fundamental role they played in the discovery of nuclear fission; Hahn received the Nobel Prize for chemistry in 1944 for this achievement. During World War II, while nominally involved in Germany's nuclear weapons program, Hahn and his assistants (including Straßmann) devoted most of their time to studying fission fragments, cataloguing about one hundred fission product isotopes. Some of this research is represented in the above two papers. 46015, 46016

## *Heisenberg's First Paper—The First Model for the Anomalous Zeeman Effect*

**84. Heisenberg, Werner** (1901-76). Zur Quantentheorie der Linienstruktur und der anomalen Zeemaneffekte. Offprint from *Zeitschrift für Physik* 8 (1922). 273-297pp. Original printed wrappers, slightly toned. Very good. $3000




**First Edition, Offprint Issue** of Heisenberg's first published paper, introducing his "core model" of the atom, which he wrote while he was a doctoral student under Arnold Sommerfeld at the University of Munich. Heisenberg's core model was an attempt to account for the anomalous Zeeman effect—the then-inexplicable splitting of atomic spectral lines into more than the "normal" three that remained unsolved until Uhlenbeck and Goudsmit's introduction of electron spin in 1925. "In his first semester Heisenberg offered a classification of the anomalous lines using thoroughly unorthodox half-integral quantum numbers. In 1922 he publicly displayed his audacity—and his intuition—in his first published paper, which offered a model for the Zeeman effect that described all of the known data in terms of the couplings between valance electrons and the remaining atomic 'core' electrons. The model, however, violated many of the basic principles of quantum theory and classical mechanics. **It thus served as both the basis for most of the subsequent work on the Zeeman effect until the advent of electron spin and as the first indication of the radical changes required for solving the quantum riddle**" (*Dictionary of Scientific Biography*; emphasis ours).

"As the first—and for the next four years the only—model for multiplets and the anomalous Zeeman effect, [Heisenberg's paper] had to be taken seriously, yet it violated nearly every quantum principle in sight. Attempts to come to terms with this dilemma occupied quantum spectroscopists for the next four years" (Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg*, p. 123). Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1922a. 50840

**85.** [**Heisenberg, Werner** (1901-76).] **Sommerfeld, Arnold** (1868-1951) and **Heisenberg.** Eine Bemerkung über relativistische Röngtendubletts und Linienschärfe. Offprint from *Zeitschrift für Physik* 10 (1922). 393-398pp. 230 x 157 mm. Original printed wrappers, tiny tear in front margin. Very good. $2000

**First Edition, Offprint Issue.** While studying quantum spectroscopy under Arnold Sommerfeld at the University of Munich, the 21-year-old Heisenberg collaborated with his professor on two papers that made use of Niels Bohr's recently-introduced correspondence principle. In their first paper, the one we are offering here, "Sommerfeld and Heisenberg discussed the relation between the relativistic X-ray doublets and the sharpness of spectral lines. Bohr had argued earlier that any quantum-theoretical calculation, yielding a difference of the energy terms smaller than the radiation losses due to classical electrodynamics, was fundamentally wrong. Hence the question had to be asked whether the higher-order relativistic corrections, which appeared to contribute essentially to the *L*-doublet states of heavy elements, still made sense. Sommerfeld and Heisenberg now calculated the classical energy losses and connected them, via a correspondence argument, to the observed linewidth, and concluded from their result that the higher-order relativistic corrections considered so far were 'perfectly consistent' with Bohr's view concerning the radiation losses" (Mehra, *The Golden Age of Theoretical Physics,* pp. 485-486). Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1922c. 50855.

**86.** [**Heisenberg, Werner** (1901-76).] **Born, Max** (1882-1970) and **Heisenberg.** Über Phasenbeziehungen bei den Bohrschen Modellen von Atomen und Molekeln. Offprint from *Zeitschrift für Physik* 14 (1923). 44-55pp. 230 x 156 mm. Original printed wrappers, a bit dust-soiled. Very good. From the library of Gregor Wentzel (1898-1978), with his signature on the front wrapper. $3000

**First Edition, Offprint Issue.** In the fall of 1922, as difficulties with the old quantum theory were mounting, Born and his student Heisenberg set out to test the validity of Niels Bohr's model of the atom as a nucleus orbited by electron shells. The two chose excited helium, with its two varied electron orbits, as the perfect test case. "By closely adhering to both quantum rules and classical mechanics, consistency would show if and exactly where the theory failed. But to handle helium, the Born-Pauli apparatus [i.e., the Born-Pauli perturbation method, published in July 1922] required extension to mechanical cases of accidental degeneracy . . . By late December 1922, Born and Heisenberg had obtained the needed extension of Born and Pauli's method. They quickly used it to test Bohr's explanation for the closing of [electron] shells in the building up of atoms, confirming the hypothesis to their own satisfaction [in the present paper] . . . The entire periodic table could be constructed by building up each successive element through the addition of another electron to the outer electron shell, each of which closed as it should at a noble gas atom. Bohr aptly named this process the building-up principle" (Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg,* pp. 146-147).

This copy is from the library of theoretical physicist Gregor Wentzel, who made notable contributions to quantum mechanics; he is best known for the Wentzel-Kramers-Brillouin approximation for finding approximate solutions to linear partial differential equations with spatially varying coefficients. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1923a. 50842

**87.** [**Heisenberg, Werner** (1901-76).] **Born, Max** (1882-1970) and **Heisenberg.** Die Elektronenbahnen im angeregten Heliumatom. Offprint from *Zeitschritft für Physik* 16 (1923). 229-243pp. 230 x 156 mm. Original printed wrappers, a bit dust-soiled. Very good. From the library of Gregor Wentzel (1898-1978), with his signature on the front wrapper. $2000

**First Edition, Offprint Issue.** After publishing their paper on phase relationships in Bohr's models of atoms and molecules (see above), Born and Heisenberg "turned at last to the excited helium atom as a careful, systematic test to prove or disprove the viability of quantum atomic theory . . . Heisenberg informed Bohr of the plan in early February 1923: 'The other work of which I wanted to write you is a general investigation of all mechanically allowed orbits of excited helium. If in the end the experimentally found terms are not included, then one knows the mechanics is wrong.' . . .

"The advantage of excited helium was that it could be treated almost exactly like a hydrogen atom—a perfect setup for perturbation theory. In an excited state, one of the two helium atoms moves in an orbit farther out from the nucleus than the other more tightly bound inner electron. Since the negative charge of the inner electron shields one of the positive charges of the nucleus, the entire effect of the inner electron and nucleus on the outer electron could be treated as a small perturbation of the motion of the single outer electron, hence as a small perturbation of the well-established hydrogen model . . . This arrangement, the simplest possible three-body case after two-body hydrogen, should definitely prove whether or not the prevailing quantum theory of the atom was valid" Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg,* p. 148). In fact, the results Born and Heisenberg obtained were "completely catastrophic" (Cassidy, p. 149), and in the present paper they concluded that "it will be necessary to introduce new hypotheses" (p. 243)

This copy is from the library of theoretical physicist Gregor Wentzel; see above. This and the above paper were the only two works Heisenberg published in 1923. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1923b. 50841

**88. Heisenberg, Werner** (1901-76). Nichtlaminare Lösungen der Differentialgleichungen für reibende Flüssigkeiten. Offprint from T. von Kármán and T. Levi-Cività, eds., *Vorträge aus dem Gebiete der Hydro- und Aerodynamik* (Berlin: Springer, 1924). 139-142pp. 232 x 157 mm. Without wrappers as issued. Very good. $1250

**First Edition, Extremely Rare Offprint Issue.** Heisenberg's lecture on "Nonlaminar solutions of the differential equations for frictional fluids," delivered at Innsbruck in 1922, formed part of the research for his doctoral thesis on hydrodynamics at the University of Munich (see below). Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1924i. 50854

## *Heisenberg's Ph.D. Thesis*

**89. Heisenberg, Werner** (1901-76). Über Stabilität und Turbulenz von Flüssigkeitsströhmen. Offprint from *Annalen der Physik*, 4th series, 74 (1924). 577-627pp. 225 x 144 mm. Without wrappers as issued. Light toning, tiny lacuna in last page not affecting text, but very good. $2000

**First Edition, Offprint Issue.** For his doctoral thesis at the University of Munich, Heisenberg was given the problem of "solving the horribly complicated equations for the stability and turbulence of flowing fluids" (Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg,* p. 150). At the time no one had yet found a way to predict the precise transition from smooth to turbulent flow in a channeled liquid, although four decades earlier Osborne Reynolds had found that a dimensionless constant—the "Reynolds number"—governed the transition to turbulence. "Heisenberg set out to derive Reynolds's results from the fundamental equations of hydrodynamics. In his 59-page thesis submitted to the Philosophical Faculty II (science) on July 10, 1923, Heisenberg divided the problem into two parts. In the first part he examined the conditions under which laminar flow becomes unstable, while in the second he investigated the role of the Reynolds number. Having already obtained, during his second semester, the solution for turbulent vortex motions between two parallel plates, and having spoken at Innsbruck on the derivation of the Reynolds number, he found little difficulty in solving either part of his thesis using various approximation and simplification techniques" (Cassidy, p. 150). A revised version of Heisenberg's thesis was published the following year in the *Annalen der Physik*, but his results were challenged by the mathematician Fritz Noether; it was not until nearly 25 years later that they were finally confirmed. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1924b. 50882

**90.** [**Heisenberg, Werner** (1901-76).] (1) **Born, Max** (1882-1970) and **Heisenberg.** Über den Einfluß der Deformierbarkeit der Ionen auf optische und chemische Konstanten. I. Offprint from *Zeitschrift für Physik* 23 (1924). 388-410pp. 228 x 156 mm. Original printed wrappers, slightly dust-soiled. (2) **Heisenberg.** Über den Einfluß der Deformierbarkeit der Ionen auf optische und chemische Konstanten. II. Offprint from *Zeitschrift für Physik* 26 (1924). 196-204pp. 230 x 156 mm. Original printed wrappers, slightly dust-soiled. Together 2 offprints. Very good. $3000

**First Editions, Offprint Issues.** In 1923, after obtaining his Ph.D. from the University of Munich, Heisenberg was hired by Max Born to work as his assistant at the University of Göttingen's Institute for Theoretical Physics, a major center for quantum theory. Some of Born and Heisenberg's investigations at this time grew out of Born's 1923-24 lectures on the properties of atomic systems, including the present papers on the deformability of ions, which provided new support for the unorthodox half-integral quantum numbers that Heisenberg had used in 1922 to formulate his core theory of the atom. "In the course of this investigation they compared the polarizability of alkali ions, as determined from the Rydberg corrections, with the observed polarizability of the neighboring noble gases to the left of the alkali elements in the periodic table. Due to the smaller nuclear charge of the noble gas atoms their polarizability should be larger than that of the corresponding alkali atoms; but this conclusion could be drawn only if . . . one used the half-integral quantum numbers *k*. Born and Heisenberg therefore declared: 'From the deformation constants of the noble gases and of noble-gas-like ions there follows the half-integral valuedness of the quantum number *k*'" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 2, p. 103).

Like most of their colleagues, Born and Heisenberg believed that the introduction of half-integral quantum numbers marked the breakdown of the old quantum theory. However, "they claimed that the half-integral quantum numbers, in fact, would show how to construct a more satisfactory atomic theory . . . [They] insisted on the fact that they had demonstrated beyond any doubt that several phenomena could be described more correctly by formally introducing half-integral quantum numbers rather than integral quantum numbers" (Mehra & Rechenberg, p. 104). Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1924c, 1924g. 50961; 50844.

**91.** [**Heisenberg, Werner** (1901-76).] **Landé, Alfred** (1888-1976) and **Heisenberg.** Termstruktur der Multipletts höherer Stufe. Offprint from *Zeitschrift für Physik* 25 (1924). 279-286pp. 230 x 156 mm. Original printed wrappers. Fine. $1250

**First Edition, Offprint Issue.** In late 1923 Heisenberg began a collaboration with Alfred Landé, an expert in spectroscopy who had come up with his own theory of the anomalous Zeeman effect a few years earlier. Heisenberg "hoped to profit from Landé's experience in organizing the observed spectra and Zeeman effects for the purpose of developing a more consistent theory of many-electron atoms . . . The authors confined themselves to discussing only the structure of the neon spectra with no external magnetic field present . . . The main content of Landé and Heisenberg's paper on the term structure of multiplets was that they introduced a new organization into the field of complex spectra" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 2, p. 118). Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1924e. 50843

**92.** **Heisenberg, Werner** (1901-76). Über eine Abänderung der formalen Regeln der Quantentheorie beim Problem der anomalen Zeemaneffekte. Offprint from *Zeitschrift für Physik* 26 (1924). 291-307pp. 232 x 157 mm. Original printed wrappers, a bit soiled. Very good. $1250

**First Edition, Offprint Issue.** "With his paper of summer 1924 on the anomalous Zeeman effects Heisenberg hoped to have come closer to the two goals which he had had in mind since fall 1923: to describe the available empirical data by a set of specific theoretical rules *and* to relate these rules to the general changes that were necessary in the existing atomic theory (i.e., the quantum theory of multiply periodic systems). As for the full description of the data, he was aware of the fact that he had only proposed certain steps in the direction of a solution" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 2, p. 122). Despite his efforts in the present paper, Heisenberg was unable to move any closer to a consistent theory of the anomalous Zeeman effects. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1924h. 50845

**93. Heisenberg, Werner** (1901-76). Über eine Anwendung des Korrespondenzprinzips auf die Frage nach der Polarisation des Fluoreszenzlichtes. Offprint from Zeitschrift für Physik 31 (1925). 617-626pp. 231 x 157 mm. Original printed wrappers, slightly soiled. Very good. From the library of H. A. Kramers (1894-1952), with his pencil signature on the front wrapper. $3000

**First Edition, Offprint Issue** of Heisenberg's paper on the application of the correspondence principle to the question of the polarization of fluorescent light. This copy is from the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory.

The correspondence principle, formulated by Niels Bohr in 1920, states that the behavior of systems described by pre-1925 quantum theory reproduces classical physics in the limit of large quantum numbers; i.e., that for large orbits and large energies quantum calculations must agree with classical calculations. By 1924, however, Bohr and his Copenhagen team of physicists were experiencing growing difficulties in applying the correspondence principle to the emission and absorption of light quanta (photons) in electromagnetic radiation.

"During a seven-month visit to [Niels] Bohr's institute at Copenhagen beginning in the fall of 1924, Heisenberg turned to the nature of light. Earlier in 1924 Bohr, Hendrik A. Kramers and John C. Slater had attempted to resolve the wave-particle duality [of light] by assuming the statistical conservation of energy and momentum in the absorption and emission of radiation [the "BKS" theory]. The proposal was already in doubt and soon refuted, but it indicated again that belief in radical change was necessary. With Bohr and Kramers, Heisenberg attempted to account for optical fluorescence and dispersion by a 'sharpened' version of Bohr's correspondence principle between classical and quantum physics" (*Dictionary of Scientific Biography*). 50885

## *Kramers-Heisenberg Formula—Stepping-Stone to the New Quantum Mechanics*

**94.** [**Heisenberg, Werner** (1901-76).] **Kramers, Hendrik Anthony** (1894-1952) and **Heisenberg.** Über die Streuung von Strahlung durch Atome. Offprint from *Zeitschrift* für *Physik* 31 (1925). 681-708pp. Original printed wrappers. Light toning, but fine. $2750

**First Edition, Offprint Issue.** During his 1924-25 residency in Niels Bohr's Institute for Theoretical Physics in Copenhagen, Heisenberg and Bohr's assistant H. A. Kramers worked together on the problem of atomic structure from the point of view of dispersion theory. "At first, this interest might appear strange because the problems of atomic structure, say, e.g., the calculation of the energy states of helium, would not seem to have any connection with the scattering of light by atoms, which was the principal concern of dispersion theory. However, Bohr and his collaborators had concluded that the problem of atomic structure could not be separated from the problem of the emission and absorption of radiation—and this could be considered as a problem of the dispersion of radiation" (Mehra & Rechenberg, *Historical Development of Quantum Theory*, 2, p. 170). Kramers and Heisenberg's joint paper on the dispersion of light by atoms contained the important Kramers-Heisenberg dispersion formula, an expression of the cross section for scattering of a photon by an atomic electron; among other things, the formula explained the phenomenon of inelastic scattering, anticipating the Raman effect. Heisenberg's work on this paper "was the final touch needed for [him] to fabricate quantum mechanics six months later" (Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg,* p. 188). Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1925b. 43379

**95. Heisenberg, Werner** (1901-76). Zur Quantentheorie der Multiplettstruktur und der anomalen Zeemaneffekt. Offprint from *Zeitschrift für Physik* 32 (1925). 841-860pp. 230 x 157 mm. Original printed wrappers, a bit dust-soiled, small crease in back wrapper. Very good. $1250

**First Edition, Offprint Issue.** Heisenberg's last paper prior to the publication of his famous "Über die quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen" (1925), which established the fundamental principles of quantum mechanics. In the present paper, on the quantum theory of multiplet structure and the anomalous Zeeman effect, Heisenberg was still working within the limitations of the old quantum theory as he tried to create a single theory out of two different Zeeman schemes. "Heisenberg was still searching for ways to calculate orbital energies, even when retreating from precise models of the atom" (Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg,* p. 193). He wrote the paper in Copenhagen in the spring of 1925, during Wolfgang Pauli's monthlong visit to Niels Bohr's Institute, and Pauli and Bohr submitted it for publication in the *Zeitschrift* after Heisenberg left Copenhagen for Göttingen. "The paper served as a tacit admission of failure by everyone" (Cassidy, p. 194)—one of the final nails in the coffin for the old quantum theory. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1925c. 50847

**96. Heisenberg, Werner** (1901-76). Über quantentheoretische Kinematik und Mechanik. Offprint from *Mathematische Annalen* 95 (1926). 683-705pp. 233 x 157 mm. Original printed wrappers, spine stapled, some fraying, minor soiling. Good to very good. From the library of H. A. Kramers (1894-1852), with his pencil signature on the front wrapper and notes and calculations on pp. 690-691 and 694. $1250

**First Edition, Offprint Issue.** After Heisenberg introduced the matrix form of quantum mechanics in his famous paper "Über quantenmechanische Umdeutung kinematischer und mechanischer Beziehung" (1925), the great German mathematician David Hilbert invited him to discuss his discovery and ensuing developments at Hilbert's Göttingen mathematical seminar. Heisenberg delivered the present summary of his work on 21 December 1925, a little over a month after completing the Born-Heisenberg-Jordan *Dreimänner* paper but a few weeks prior to its publication in February 1926 in the *Zeitschrift für Physik*. Heisenberg cited the *Dreimänner* paper on the first page of the present work.

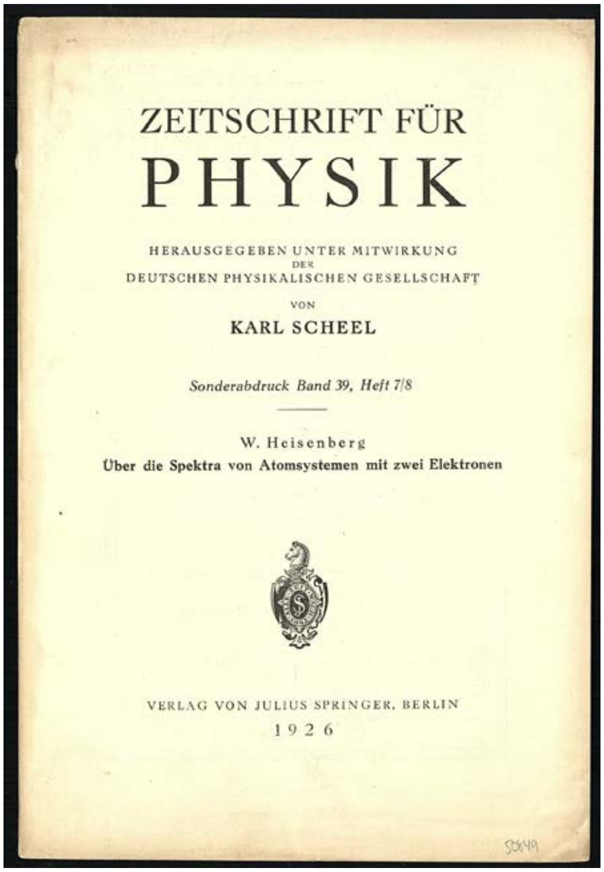
This copy of Heisenberg's paper is from the library of H. A. Kramers, one of the major contributors to quantum theory; his pencil notes and calculations appear on pp. 690-691 and 694. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1926b. 50881

**97. Heisenberg, Werner** (1901-76) and **Pascual Jordan** (1902-80). Anwendung der Quantenmechanik auf das Problem der anomalen Zeemaneffekte. Offprint from *Zeitschrift für Physik* 37 (1926). 263-277pp. 230 x 158 mm. Original printed wrappers. Very good. $2000

**First Edition, Offprint Issue.** In February 1926, Born, Heisenberg and Jordan published their famous *Dreimännerarbeit* (three-man paper) establishing the basic postulates of quantum matrix mechanics. A few months later Jordan and Heisenberg followed up with the present paper applying quantum mechanics to the problem of the anomalous Zeeman effect. "Heisenberg and Jordan applied electron spin and the full apparatus of quantum theory to what they called a calculation of the 'quantum-mechanical behavior of the atomic model characterizing this [spin] hypothesis . . . Among the fruits of the Heisenberg-Jordan combination of spin and matrices were derivations of the doublet fine structure, Landé's *g*-factors, and the old Sommerfeld-Voigt equations . . . For Heisenberg and Jordan, such successes constituted important support not only for spin but for matrix mechanics itself" (Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg*, pp. 209-210). Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1926c. 50850

## *Classic in Atomic Theory*

**98. Heisenberg, Werner** (1901-76). Über die Spektra von Atomsystemen mit zwei Elektronen. Offprint from *Zeitschrift für Physik* 39 (1926). 499-518pp. Original printed wrappers, a bit dust-soiled, small marginal tear in the back wrapper. Very good. $4500




**First Edition, Offprint Issue** of Heisenberg's landmark calculation of the helium and helium-like spectra; i.e., atomic systems with two electrons. Heisenberg had tackled the helium problem four years earlier, using the old quantum theory of atomic structure, but his use of half-integral quantum numbers was both controversial and unsatisfactory. By the spring of 1926, with the advent of Heisenberg's new quantum mechanics, "such quantum numbers could be shown to arise at two different places in atomic theory: first, in the quantum mechanical formalism of angular momentum; and second, in the hypothesis of electron spin. The latter concept, especially, offered great hopes in providing a final, satisfactory solution of the helium problem" (Mehra & Rechenberg, *Historical Development of Quantum Theory,* 5, p. 736).

Heisenberg found the key to solving the helium problem by taking into account not only electron spin but the Coulomb repulsion of the helium atom's two electrons, which gave rise to a new strong force that accounted for helium's large singlet-triplet splitting. In June 1926 he submitted a paper to the *Zeitschrift* giving his method for calculating the helium atom's energy states, following it a month later with the present paper containing his actual calculations for two-electron systems, including the general formula for the fine structure of two-electron spectra (p. 514). Heisenberg's helium calculation "constituted a major triumph in quantum mechanics. It remained one of the standard approaches to two-electron problems which would be discussed in all later reviews of the topic; Heisenberg's successors would improve the approximation methods . . . but the basic ideas did not have to be altered. In this respect, **Heisenberg's helium calculation became a classic in atomic theory**" (Mehra & Rechenberg, 5, p. 745; emphasis ours). Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1926e. 50849

**99. Heisenberg, Werner** (1901-76). Schwankungserscheinungen und Quantenmechanik. Offprint from *Zeitschrift für Physik* 40 (1926). 501-506pp. 230 x 157 mm. Original printed wrappers, light marginal toning. Very good. $1500

**First Edition, Offprint Issue.** In the present paper on fluctuation phenomena and quantum mechanics, Heisenberg "wished to close the gap between the treatment of radiation in the three-man paper and the light-quantum approach of Einstein" (Mehra & Rechenberg, *The Historical Development of the Quantum Theory,* 6, p. 143); the paper is representative of the then-running debate between adherents of Heisenberg's matrix mechanics and Erwin Schrödinger's wave mechanics, which had been introduced in a four-part paper published between March and September 1926. "[Heisenberg's] study confirmed the claim of Bohr, Born, Heisenberg, Jordan, and their close associates that —in contrast to Schrödinger's assertion—quantum mechanics cannot do without quantum jumps. Heisenberg proved the anti-Schrödinger opinion by applying matrix methods: he showed that the typical wave-mechanical beat phenomena resulted, and insisted at the same time that 'quantum mechanics always agrees with the fluctuation formulae, as required on the discontinuum theory'" (Mehra & Rechenberg, 6, p. 77). Heisenberg's results proved useful to Paul Dirac when Dirac was composing his fundamental paper "The physical interpretation of the quantum dynamics" (1927), which introduced his transformation theory. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings*, 1927a (sic). 50848

## *Heisenberg's First Use of Group Theory in Quantum Mechanics*

**100. Heisenberg, Werner** (1901-76). Mehrkörperprobleme und Resonanz in der Quantenmechanik. II. Offprint from *Zeitschrift für Physik* 41 (1927). 239-267pp. 230 x 157 mm. Original printed wrappers, spine split, signatures loose, light spotting. Good copy. From the library of H. A. Kramers (1894-1952), with his pencil signature on the front wrapper. $2500

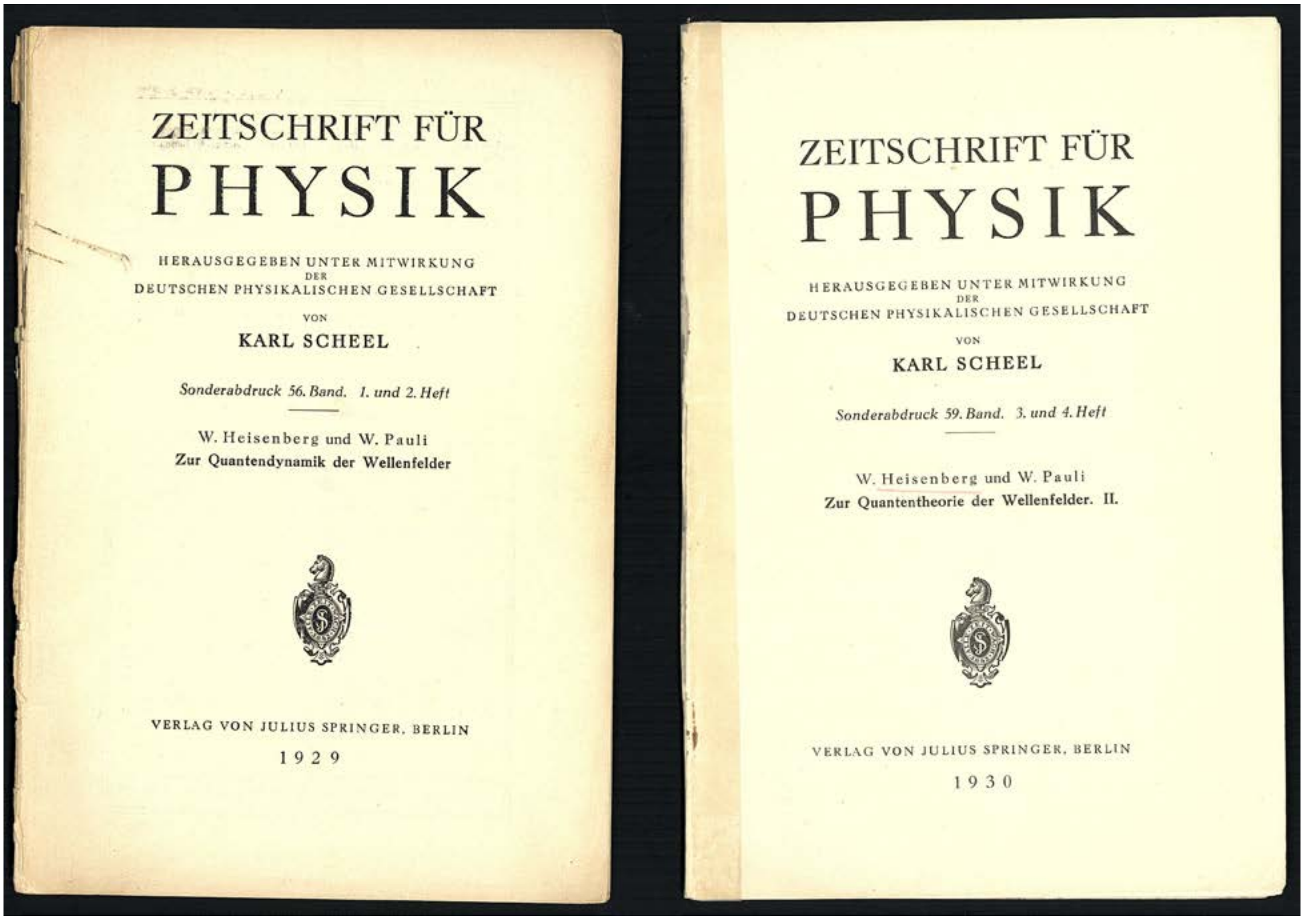
**First Edition, Offprint Issue.** Heisenberg's first use of mathematical group theory in quantum mechanics, a method that he and Eugene Wigner independently introduced in early 1927. In this paper Heisenberg discussed the quantum statistics of many-electron systems: "Dirac had earlier treated this problem on the basis of wave mechanics; now it became a matter of principle for Heisenberg to examine it again from the point of view of matrix mechanics" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, p. 150). This copy of Heisenberg's paper is from the library of H. A. Kramers, one of the major contributors to quantum theory. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1927b. 50887

**101. Heisenberg, Werner** (1901-76). Zur Theorie des Ferromagnetismus. Offprint from *Zeitschrift für Physik* 49 (1928). 619-636pp. 231 x 157 mm. Original printed wrappers, creased vertically, light soiling. Very good. From the library of physicist Gregor Wentzel (1898-1978), with his signature on the front wrapper. $2500

**First Edition, Offprint Issue** of Heisenberg's quantum-mechanical explanation of ferromagnetism, a phenomenon that had long baffled scientists. "In 1928 [Heisenberg] showed that a quantum-mechanical exchange integral that had played a crucial role in his earlier solution of the helium problem could account for the strong molecular magnetic field in the interior of ferromagnetic materials" (*Dictionary of Scientific Biography*). Heisenberg had come up with his hypothesis—which involved the parallel alignment of all electron spins in a metal—prior to the publication of the present paper, "but he couldn't prove it until 1928. The published derivation, which he submitted to the *Zeitschrift für Physik* in May 1928, required the application of mathematical group theory to quantum mechanics, which had recently been achieved by Eugene P. Wigner, Hermann Weyl, and others . . . Once applied, the widely disputed, longtime puzzle of ferromagnetism readily succumbed" (Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg*, p. 284). Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1928a. 50878

**102. Heisenberg, Werner** (1901-76). Zur Theorie des Ferromagnetismus. Offprint from *Zeitschrift für Physik* 49 (1928). 619-636pp. 231 x 157 mm. Original printed wrappers, spine splitting, light soiling and wear. Very good. From the library of H. A. Kramers (1894-1952), with his pencil signature on the front wrapper. $2500

**First Edition, Offprint Issue.** This copy is from the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory. 50889



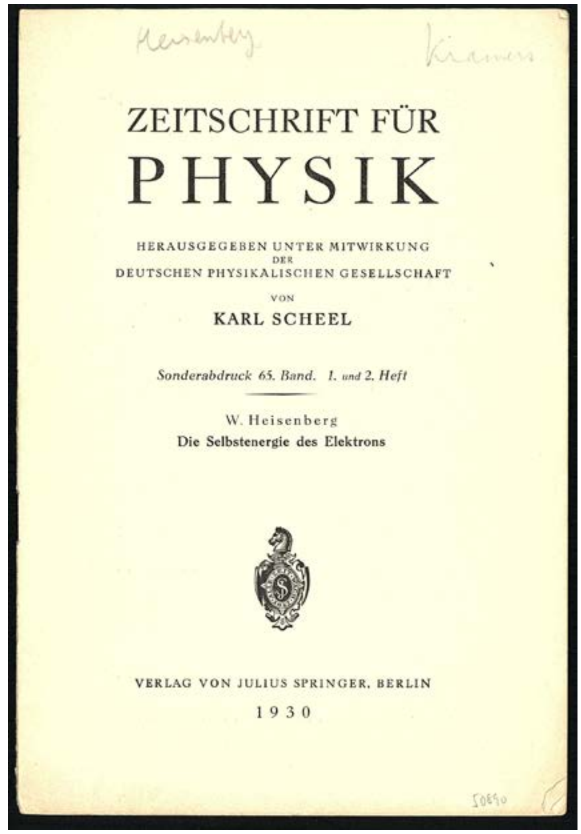

## *Formal Invention of Quantum Electrodynamics*

**103. Heisenberg, Werner** (1901-76) and **Wolfgang Pauli** (1900-1958). (1) Zur Quantendynamik der Wellenfelder. Offprint from *Zeitschrift* für *Physik* 56 (1929). 61pp. 231 x 160 mm. Original printed wrappers, spine repaired. (2) Zur Quantentheorie der Wellenfelder. II. Offprint from *Zeitschrift* für *Physik* 59 (1930). 168-190pp. 231 x 160 mm. Original printed wrappers, spine repaired with clear tape. Together 2 items. Small mark from paper clip on wrappers of no. (1), small tear in front wrapper of no. (2), but very good. $12,500

**First Editions, Offprint Issues.** Heisenberg and Pauli's two-part paper contains the first full-fledged relativistic quantum field theory, representing the "formal invention of quantum electrodynamics" (Miller, *Early Quantum Electrodynamics: A Source Book*, p. xiii). "This extremely technical and mathematical branch of quantum physics, the foundations of which were laid by Heisenberg, Dirac, Pauli, Jordan, and their colleagues during the late 1920s and early 1930s, continues to this day with much the same program and approach . . . [Heisenberg was] a leading member of the small band of abstract theorists who established the program and laid the foundations of relativistic quantum field theory as it has been pursued ever since" (Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg*, p. 276).

In this paper—the only one that Heisenberg and Pauli co-authored—the two physicists attempted to establish "a consistent extension of the quantum formalism that would yield a satisfactory unification of quantum mechanics and relativity theory . . . In 1929, drawing upon the work of Dirac, Jordan, Oskar Klein, and others, Heisenberg and Pauli succeeded in formulating a general gauge-invariant relativistic quantum field theory by treating particles and fields as separate entities interacting through the intermediaries of field quanta. The formalism led to the creation of a relativistic quantum electrodynamics, equivalent to that developed by Dirac, which, despite its puzzling negative energy states, seemed satisfactory at low energies and small orders of interaction. But at high energies, where particles approach closer than their radii, the interaction energy diverges to infinity. Even at rest, a lone electron interacting with its own field seemed to possess an infinite self-energy . . . Attention was directed to the resolution of such difficulties for more than two decades" (*Dictionary of Scientific Biography*). Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1930a. Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, pp. 312-26. 43254

**104. Heisenberg, Werner** (1901-76). Die Selbstenergie des Elektrons. Offprint from *Zeitschrift für Physik* 65 (1930). 4-13pp. 230 x 157 mm. Original printed wrappers, a bit soiled and worn, small split in spine. Very good. From the library of H. A. Kramers (1894-1952), with his pencil signature on the front wrapper and a few pencil underlinings, probably his, on the first 2 pages. $6000




**First Edition, Offprint Issue.** Heisenberg's paper, published two years after Dirac announced his relativistic equation of the electron, tackles the problem of the electron's self-energy, one of the most difficult (and still unresolved) issues in quantum field theory. In both classical and quantum physics, if an electron is treated as a massless point, as required by relativity theory, the radiation field surrounding it becomes infinitely large, causing the divergence of the electron's energy to infinity. In his paper "Heisenberg showed that, even if the electrons travel so fast that their infinite self-energies can be neglected (because of relativistic effects), Dirac's negative energy states still destroyed any attempt to treat the most basic situation—one electron moving alone through empty space., surrounded by its own electric field. Because of the infinite number of negative states, the calculated energy of that field also exploded to infinity. From this he concluded: 'It is not probable that we will arrive at a solution without considerable alterations of the quantum theory of wave fields'" (Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg,* p. 288). This paper is one of eleven early QED papers featured in A. I. Miller's *Early Quantum Electrodynamics: A Source Book* (1994).

This copy of Heisenberg's paper is from the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1930b. 50890

**105. Heisenberg, Werner** (1901-76). Fortschritte in der Theorie des Ferromagnetismus. Offprint from *Metallwirtschaft* 9 (1930). [2]pp. on single sheet. 310 x 235 mm. Without wrappers as issued. Horizontally creased, edges a bit frayed, but good to very good. From the library of Walther Gerlach (1889-1979), with his characteristic red-ink docketing on the first page. $1250

**First Edition, Offprint Issue.** On advances in the theory of ferromagnetism. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1930e. 50905

**106. Heisenberg, Werner** (1901-76). Über Energieschwankungen in einem Stahlungsfeld. Offprint from *Berichten der mathematisch-physischen Klasse der Sächsischen Akademie der Wissenschaften zu Leipzig* 83 (1931). 3-9pp. 227 x 157 mm. Original printed wrappers, slightly sunned. Very good. $950

**First Edition, Offprint Issue.** Heisenberg's paper discusses the problem of energy fluctuation in a radiation field, a question relating to quantum electrodynamics (QED). Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1931a. Mehra & Rechenberg, *The Historical Development of Quantum Theory*, 6, p. 916 (note 1026). 50858

**107. Heisenberg, Werner** (1901-76). Zum Paulischen Ausschließungsprinzip. Offprint from *Annalen der Physik*, 5th series, 10 (1931). 888-904pp. 221 x 145 mm. Without wrappers as issued. Lower margin a bit toned but very good. From the library of Gregor Wentzel (1898-1978), with his pencil signature on the front wrapper. $2250

**First Edition, Offprint Issue.** Heisenberg's paper on the Pauli exclusion principle—which states that two or more identical particles with half-integer spins cannot occupy the same quantum state simultaneously within a quantum system—made use of Dirac's theory of "holes" in dealing with non-relativistic problems of atomic and solid-state theory. Reviving Pauli's 1925 suggestion that "some equivalence should exist between atomic systems having *n* electrons and those having *n* 'holes' with respect to closed shells," Heisenberg "demonstrated the validity of the suggestion with the help of the (nonrelativistic) quantum field theory . . . Heisenberg thus threw light on some previously treated problems with the help of the concept of 'holes' that would become fruitful far beyond solid-state physics" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, p. 621).

This copy is from the library of Gregor Wentzel, who made notable contributions to quantum mechanics; he is best known for the Wentzel-Kramers-Brillouin approximation for finding approximate solutions to linear partial differential equations with spatially varying coefficients. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1931e. 50861

**108. Heisenberg, Werner** (1901-76). Bemerkungen der Strahlungstheorie. Offprint from *Annalen der Physik,* 5th series, 9 (1931). 338-346pp. Without wrappers as issued. 223 x 146 mm. Very good. From the library of Walther Gerlach 1889-1979), with his initials in pencil and characteristic red-ink docketing on p. 338. $1750

**First Edition, Offprint Issue.** "Almost on the eve of jumping off into nuclear physics, Heisenberg formulated a method for applying time-dependent perturbation theory to the interaction between a semiclassical radiation field and a q-number formulation of Dirac's theory of the electron with a wave function . . . Heisenberg's reason for formulating this calculational method was to connect quantum electrodynamics more closely than ever with 'intuitive conceptions of classical theory and of wave mechanics,' thereby with the correspondence principle too" (Miller, p. 45). Heisenberg's paper is one of the eleven early QED papers featured in Miller's *Early Quantum Electrodynamics: A Source Book* (1994). This copy is from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1931b. Miller, "Frame-setting essay," *Early Quantum Electrodynamics: A Source Book*, pp. 3-118. 50906

**109. Heisenberg, Werner** (1901-76). Zur Theorie der Magnetostriktion und der Magnetisierungskurve. Offprint from *Zeitschrift für Physik* 69 (1931). 287-297pp. 229 x 155 mm. Original printed wrappers, small rust stain on back wrapper. Very good. From the library of Walther Gerlach 1889-1979), with his initials in pencil and characteristic red-ink docketing on the front wrapper. $1500

**First Edition, Offprint Issue.** Heisenberg's paper applies quantum mechanics to the theory of the magnetization curve. This copy is from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1931c. 50898

**110. Heisenberg, Werner** (1901-76). Über die inkohärente Streuung von Röntgenstrahlen. Offprint from *Physikalische Zeitschrift* 32 (1931). 737-740pp. 272 x 198 mm. Bifolium; without wrappers as issued. Leaves separated at spine, some creasing, chipping and fraying. Good copy. From the library of H. A. Kramers (1894-1952), with his pencil signature on the first page. $1250

**First Edition, Offprint Issue.** Applying quantum mechanics to the incoherent scattering of X-rays by nuclei. This copy is from the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1931f. 50893

**111. Heisenberg, Werner** (1901-76). Die Rolle der Unbestimmtheitsrelationen in der modernen Physik. Offprint from *Monatsheften für Mathematik und Physik* 38 (1931). 8pp. 230 x 155 mm. Original printed wrappers. Fine. $750

**First Edition, Offprint Issue**. On the role of uncertainty relations in modern physics. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1931i. 50853

## *Heisenberg's First Paper on Cosmic Rays—From Kramers's Library*

**112. Heisenberg, Werner** (1901-76). Theoretische Überlegungen zur Höhenstrahlung. Offprint from *Annalen der Physik*, 5th series, 13 (1932). 430-452pp. 224 x 145 mm. Without wrappers as issued, signatures separated. Very good. From the library of H. A. Kramers, with his pencil signature on the first page. $2750

**First Edition, Offprint Issue.** "The first of [Heisenberg's] many substantial papers on cosmic-ray phenomena in the 1930s . . . As Heisenberg wrote in the introduction, he intended 'to discuss in detail the most important experiments on cosmic radiation from the point of view of the existing theories, and to state at which points the experiments roughly agree with the theoretical expectation, and where such large deviations show up that one has to be prepared for important surprises' . . . He then discussed, in particular, the deceleration of electrons when passing through matter and several typical cosmic-ray phenomena (such as those observed in the absorption curves), and he explained the existing discrepancies between theory (especially, the Klein-Nishina formula) and experiment on account of 'the failure, in principle, of Dirac's radiation theory or the equivalent quantum electrodynamics" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, p. 904). This copy is from the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1932a. 50894

**113. Heisenberg, Werner** (1901-76). Über den Bau der Atomkerne. III. Part 3 *only* of 3 parts. Offprint from *Zeitschrift für Physik* 80 (1933). 587-596pp. 230 x 156 mm. Original printed wrappers. Fine. $3500

**First Edition, Offprint Issue.** The third and final part of Heisenberg's groundbreaking paper containing "a quantum mechanics of the nucleus that laid the foundations of nuclear physics as it is still practiced" (Cassidy, p. 290). Heisenberg's achievement followed upon Chadwick's discovery of the neutron, announced in March 1932. Prior to this discovery only three elementary particles had been known: the electron, the proton and the photon. The atomic nucleus was thought to consist of protons and electrons, but this hypothesis gave rise to great difficulties in understanding the physics of the nucleus. Chadwick's new elementary particle, added to those already known, gave Heisenberg his "long-sought chance" to create a workable quantum theory of the atomic nucleus. The first two parts of Heisenberg's paper, not present here, were published in vols. 77 and 78 of the *Zeitschrift für Physik.* Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg,* pp. 292-293. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1933a. Mehra and Rechenberg, *Historical Development of Quantum Theory*, 6, pp. 809-812. 58062

**114. Heisenberg, Werner** (1901-76). Über die Streuung von Röntgenstrahlen an Molekülen und Kristallen. Offprint from *Ergebnisse der technischen Röntgenkunde* 3 (1933). 26-31pp. 236 x 158 mm. Original printed wrappers. one corner a little bent. Fine. $1250

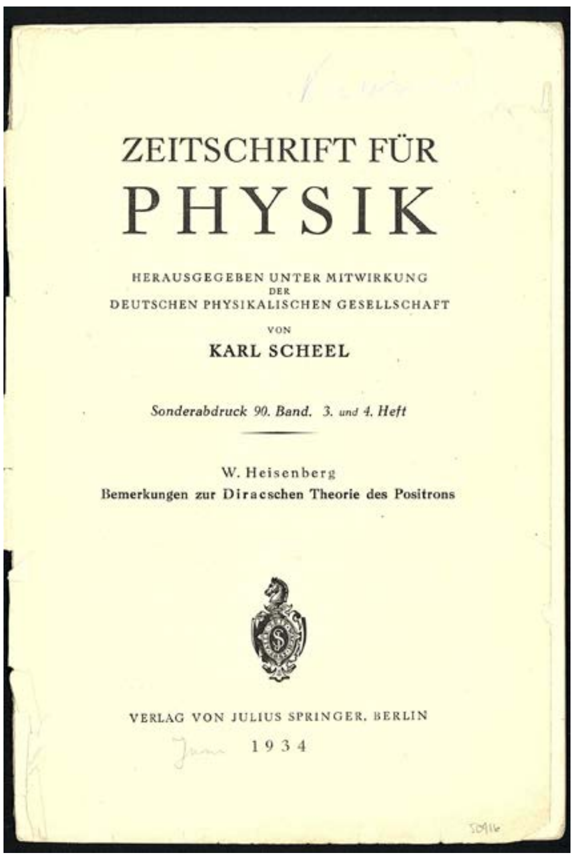
**First Edition, Offprint Issue.** On the scattering of X-rays by molecules and crystals. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1933b. 50863

**115. Heisenberg, Werner** (1901-76). Zur Geschichte der physikalischen Naturerklärung. Offprint from from *Berichten der mathematisch-physischen Klasse der Sächsischen Akademie der Wissenschaften zu Leipzig* 85 (1933). 29-40pp. 225 x 156 mm. Original printed wrappers, slightly sunned. Very good. From the library of H. A. Kramers (1894-1952), with his stamp on the front wrapper. $750

**First Edition, Offprint Issue.** On the history of the physical explanation of Nature. From the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1933c. 50913

## *Heisenberg's Theory of the Positron*

**116. Heisenberg, Werner** (1901-76). Bemerkungen zur Diracschen Theorie des Positrons. Offprint from *Zeitschrift für Physik* 90 (1934). 209-231pp. 231 x 157 mm. Original printed wrappers, detached, front wrapper upper corner torn, some fraying. Good copy. From the library of H. A. Kramers (1894-1952), with his signature in blue pencil on the front wrapper and marginal notes and equations on a few pages. $6000




**First Edition, Offprint Issue.** This copy is from the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory; pages 220-221 are extensively annotated with notes and equations in his hand.

In 1930 and 1931 Dirac published his "holes" theory of protons and electrons, in which he predicted the existence of an "anti-electron"—a prediction confirmed experimentally in 1932 when Carl David Anderson discovered the positron. The following year Heisenberg and Wolfgang Pauli turned their attention to Dirac's holes theory, hoping to incorporate it into a new joint program on quantum electrodynamics. This ended in disappointment—Pauli found it nearly impossible to calculate anything with Dirac's formulae—but Heisenberg suggested a different hole scheme, and after some discussion Pauli proposed that he, Heisenberg and Viktor Weisskopf collaborate on a three-man paper containing the formulation of the general theory. Pauli's plan did not come about, but Heisenberg formulated part of the theory and published it in the present paper, "Remarks on Dirac's theory of the positron."

The paper was in two sections. The first, titled "Visualizable theory of matter waves," Heisenberg "used Dirac's density matrix and the Hartree-Fock approximation explicitly and showed that Dirac's subtraction procedure in the *R*-matrix (which exhibited symmetry between the electrons and holes) was indeed compatible with the usual conservation laws . . . In the second part—entitled 'Quantentheorie der Wellenfelder' (Quantum theory of wave fields)—Heisenberg indeed went beyond Dirac's Hartree-Fock approximation method; he especially introduced *q*-number wave fields and developed both a perturbation method . . . and a different iteration procedure, thereby expanding the Hamiltonian up to the fourth order of the electric charge. As Abraham Pais noted later, '**Heisenberg gives for the first time the foundations for the quantum electrodynamics of the full Dirac-Maxwell set of equations in the way we know it today**'" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, pp. 918-919; emphasis ours). This paper is one of eleven early QED papers featured in A. I. Miller's *Early Quantum Electrodynamics: A Source Book* (1994). Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1934a. 50916

**117. Heisenberg, Werner** (1901-76). Berichtigung zu der Arbeit: "Bemerkungen zur Diracschen Theorie des Positrons." Offprint from *Zeitschrift für Physik* 92 (1934). [1] page, on single sheet. 228 x 157 mm. Without wrappers as issued. Edges frayed and chipped, some creasing. Good copy. $1500

**First Edition, Extremely Rare Offprint Issue** of Heisenberg's correction to his paper on Dirac's positron theory. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1934b. 50917

**118. Heisenberg, Werner** (1901-76). Über die mit der Entstehung von Materie aus Strahlung verknüpften Ladungsschwankungen. Offprint from *Berichten der mathematisch-physischen Klasse der Sächsischen Akademie der Wissenschaften zu Leipzig* 86 (1934). 317-322pp. 227 x 150 mm. Original printed wrappers, a little worn. Very good. From the library of H. A. Kramers (1894-1952), with his pencil signature on the front wrapper. $2000

**First Edition, Offprint Issue.** Following his important paper on Dirac's theory of the positron, Heisenberg here discussed the problem of charge fluctuations in Dirac's theory. The paper raised the following question: "what happen[s] to the polarization effect considered by [Wendell] Furry and [Robert] Oppenheimer in 1933 if calculated in the new Dirac-Heisenberg positron theory?" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, p. 921). This question was addressed the following year in papers by Robert Serber, Hans Euler, Bernhard Kockel; and in 1936 by Viktor Weisskopf. This copy is from the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1934c. 50895

**119. Heisenberg, Werner** (1901-76). Wandlungen der Grundlagen der exakten Naturwissenschaft in jüngster Zeit. Offprint from *Die Naturwissenschaften* 22 (1934). 669-675pp. 269 x 196 mm. Without wrappers as issued. Creased horizontally, spine splitting, some fraying. Good copy. From the library of H. A. Kramers (1894-1952), with his stamp on the first page. $1250

**First Edition, Offprint Issue.** On recent changes in the foundation of the exact natural sciences. This copy is from the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1934e. 50975

**120. Heisenberg, Werner** (1901-76). Nobel-Vortrag in Stockholm am 11. Dezember 1933 gehalten. 13pp. Stockholm: P. A. Nordsted & Söner, 1934. 246 x 166 mm. Original printed wrappers, upper corner a little bent. Very good. $450

**First Edition, Offprint Issue** of Heisenberg's Nobel Prize lecture. Heisenberg received the 1932 Nobel Prize in physics for his contributions to quantum mechanics. The lecture was published in book form the following year in *Les prix Nobel en 1933* (Stockholm: P. A. Nordstedt & Söner, 1935). Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1935e.1. 50866

**121. Heisenberg, Werner** (1901-76). Atomtheorie und Naturerkenntnis. Offprint from *Mitteilungen des Universitätsbundes Göttingen* 16 (1934). 9-20pp. 233 x 161 mm. Original printed wrappers, a bit sunned. Very good. $400

**First Edition, Offprint Issue.** Lecture on atomic theory and the knowledge of nature. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1934k. 50864

**122. Heisenberg, Werner** (1901-76). Die Struktur der leichten Atomkerne. Offprint from *Zeitschrift für Physik* 96 (1935). 228 x 154 mm. Original printed wrappers, slightly dust-soiled. Fine. $375

**First Edition, Offprint Issue.** Heisenberg's last technical paper on nuclear structure. In the paper, which discusses the structure of light atomic nuclei, "[Heisenberg] proposed to replace the Thomas-Fermi approximation method, which had been preferred thus far and accounted badly for the data on light nuclei, by a Hartree-Fock method" (Mehra & Rechenberg, *The Historical Development of Quantum Physics,* 6, p. 973). Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1935a. 50867

**123. Heisenberg, Werner** (1901-76). Bemerkungen zur Theorie des Atomkerns. Offprint from *Peter Zeeman 1865-1935: Verhandelingen op 25 Mei 1935 aangeboden aan Professor Dr. P. Zeeman* (The Hague: Nijhoff, 1935). 108-116pp. 242 x 162 mm. Original printed wrappers, one corner creased. Very good. $350

**First Edition, Offprint Issue**. Remarks on the theory of the atomic nucleus. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1935d. 50865

**124. Heisenberg, Werner** (1901-76). Udviklingen af Kvanteteoriens principielle efter 1925. Offprint from *Fysisk Tidsskrift* 33 (1935). 96-101pp. 235 x 156 mm. Original printed wrappers, slightly sunned, one corner chipped. Very good. $350

**First Edition, Offprint Issue**. On the development of quantum theory after 1925. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1935c. 50888

**125. Heisenberg, Werner** (1901-76) and **Hans Euler** (1909-41). Folgerungen aus der Diracschen Theorie des Positrons. Offprint from *Zeitschrift fur Physik* 98 (1936). 714-732pp. 230 x 157 mm. Original printed wrappers, small splits in spine. Very good. Numerous equations in pencil on the front wrapper, likely in the hand of H. A. Kramers (1894-1952), the former owner of several other offprints offered here. $2000

**First Edition, Offprint Issue.** "In 1935 Heisenberg and his assistant Hans Euler discovered that nonlinear interactions in positron theory, which yielded photon-photon scattering, could be represented by treating the electron as possessing a minimum size, below which the interferences predominated" (*Dictionary of Scientific Biography*). In his 1993 review of the Heisenberg-Euler paper, Heinrich Mitter stated that "the result of the paper until today remains one of the few, in which the summation of perturbation theory contributions succeeded [fully]" (quoted in Mehra & Rechenberg, *The Historical Development of Quantum Physics,* 6, p. 922). Heisenberg and Euler submitted their paper to the *Zeitschrift* in December 1935; it appeared in print in February 1936.

This copy is likely from the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory; a number of other offprints in this collection bear similar equations in Kramers's hand. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1936a. 50896

**126. Heisenberg, Werner** (1901-76). (1) Zur Theorie der "Schauer" in der Höhenstrahlung. Offprint from *Zeitschrift für Physik* 101 (1936). 533-540pp. 228 x 157 mm. Original printed wrappers. From the library of Walther Gerlach (1889-1979), with his initials in pencil and characteristic red-ink docketing on the front wrapper. (2) Zur Theorie der explosionsartigen Schauer in der kosmischen Strahlung. II. Offprint from *Zeitschrift für Physik* 113 (1939). 61-86pp. 230 x 156 mm. Original printed wrappers, small split in spine. Together 2 offprints. Very good. $950

**First Editions, Offprint Issues.** In 1934 Louis de Broglie proposed a "neutrino" theory of light, which proposed that photons were composite particles formed from neutrino-antineutrino pairs. Both Heisenberg and Wolfgang Pauli found this theory "very suggestive," as it "supported their own desire to establish a relation between Enrico Fermi's β-decay constant (derived experimentally) and the fine structure constant . . . Indeed, if one took the prevailing concept of nuclear forces as being described by the Fermi-field theory . . . the connection between light and neutrinos suggested the possibility of obtaining eventually a unified quantum field theory of all electromagnetic and nuclear forces" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, pp. 937-938). Heisenberg took a step toward this goal in his 1936 paper, which addressed the phenomenon of cosmic ray "showers," or spontaneous bursts of secondary particles in cosmic radiation when registered at high altitudes. Heisenberg attempted to use the Fermi field theory to predict these showers, interpreting them as "the simultaneous production of multiple pairs of neutrinos and electrons" (Mehra & Rechenberg, p. 939). Until 1937, when Oppenheimer and Heitler published their QED-based theories of cosmic ray showers, Heisenberg's remained the most plausible explanation of this phenomenon. In 1939 Heisenberg published a second paper (no. [2] above) in which he discussed the formation of explosive cosmic-ray showers in the vector-meson theory.

Our copy of Heisenberg's 1936 paper is from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1936b, 1939a. 50914, 50873

**127. Heisenberg, Werner** (1901-76). Zur Theorie der "Schauer" in der Höhenstrahlung. Offprint from *Zeitschrift für Physik* 101 (1936). 533-540pp. 228 x 157 mm. Original printed wrappers. Fine. From the library of H. A. Kramers (1894-1952), with his stamp on the front wrapper. $1750

**First Edition, Offprint Issue.** From the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory. 50915

**128. Heisenberg, Werner** (1901-76). (1) Der Durchgang sehr energiereicher Korpuskeln durch den Atomkern. Offprint from *Berichten der mathematisch-physischen Klasse der Sächsischen Akademie der Wissenschaften zu Leipzig* 89 (1937). 369-384pp. 226 x 156 mm. Original printed wrappers, vertically creased, light soiling. (2) Der Durchgang sehr energiereicher Korpuskeln durch den Atomkern. Offprint from *Nuovo cimento* 15 (1938). 4pp. 249 x 175 mm. Bifolium; without wrappers as issued. Tiny tear at spine, edges a bit creased. Together 2 offprints. Very good. $1250

**First Editions, Offprint Issues.** On the passage of high-energy corpuscles through the atomic nucleus. No. (1) is the complete paper, delivered before the Sächsischen Akademie der Wissenschaften on 8 November 1937; no. (2) is a summary. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1937b, 1938c. 50868, 50874

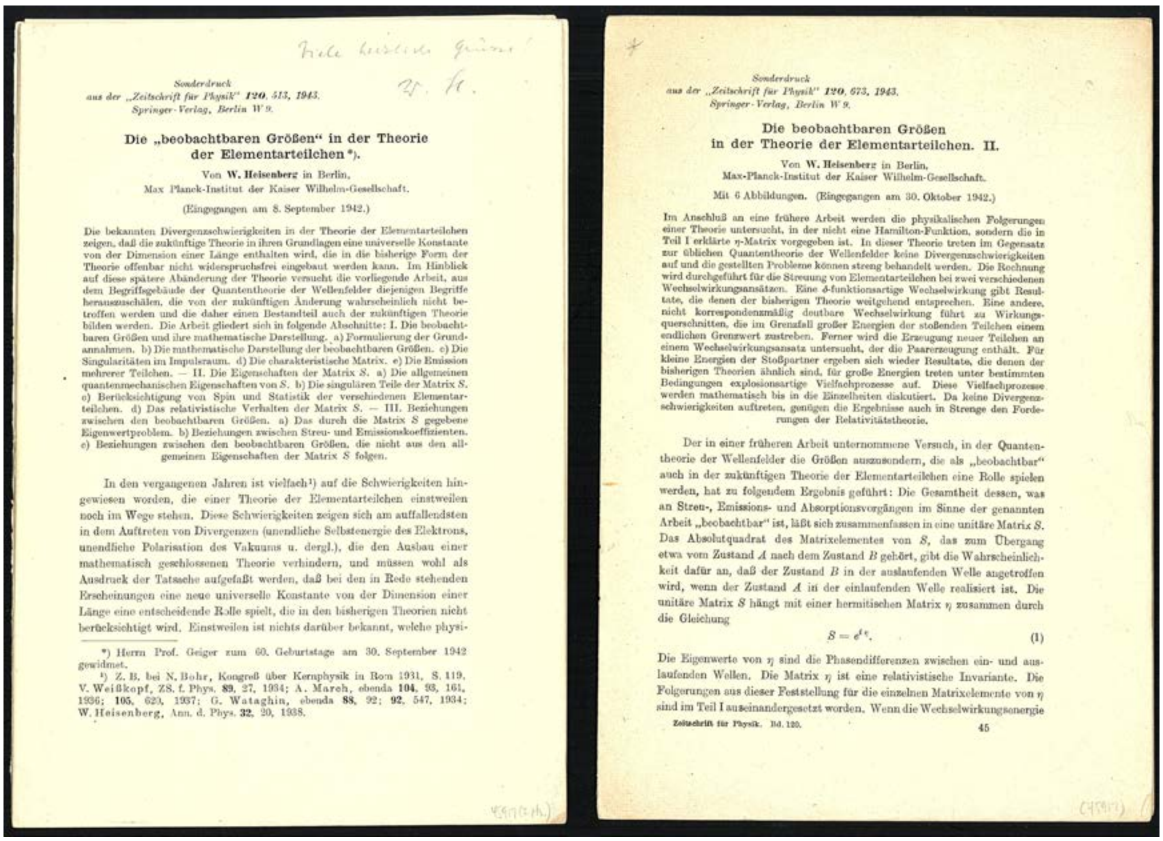
**129. Heisenberg, Werner** (1901-76). (1) Über die in der Theorie der Elementarteilchen auftretende universelle Länge. Offprint from *Annalen der Physik*, 5th series, 32 (1938). 20-33pp. 231 x 156 mm. Without wrappers as issued. Light toning. (2) Die Grenzen der Anwendbarkeit der bisherigen Quantentheorie. Offprint from *Zeitschrift für Physik* 110 (1938). 251-266pp. 230 x 156 mm. Original printed wrappers, vertically creased, light toning. Together 2 offprints. Very good. $2500

**First Editions, Offprint Issues.** In the mid-1930s, while researching high-energy collisions of elementary particles in cosmic rays, Heisenberg came up with the idea of a universal minimum length—about the size of an electron—which remained a permanent feature of his physics going forward. He expressed this idea in the above two papers, "On the universal length entering into the theory of elementary particles" and

"On the limitation of the applicability of the present quantum theory." "The main argument put forward by Heisenberg was the following: In the field theories of nuclear forces (as in quantum field theory in general), a universal length $r_0 = e^2/mc^2 = 2.81 \times 10^{-13}$—the classical electron radius, which agreed closely with the Compton wavelength of the Yukawa or cosmic-ray particle—played a fundamental role" (Mehra & Rechenberg, *The Historical Development of Quantum Theory*, 6, p. 956). The first paper listed above is one of eleven early QED papers featured in A. I. Miller's *Early Quantum Electrodynamics: A Source Book* (1994). Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1938a, 1938e. 50911, 50870

**130. Heisenberg, Werner** (1901-76). Die Absorption der durchdringenden Komponente der Höhenstrahlung. Offprint from *Annalen der Physik,* 5th series, 33 (1938). 594-599pp. 233 x 155 mm. Without wrappers as issued. Light toning but very good. $500

**First Edition, Offprint Issue.** On absorption of the penetrating component of cosmic radiation. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1938b. 50872


Viele herzliche Grüsse! W. H.

Sonderdruck
aus der „Zeitschrift für Physik" **120**, 513, 1943.
Springer-Verlag, Berlin W 9.

**Die „beobachtbaren Größen" in der Theorie der Elementarteilchen *).**

Von **W. Heisenberg** in Berlin,
Max Planck-Institut der Kaiser Wilhelm-Gesellschaft.

(Eingegangen am 8. September 1942.)

Die bekannten Divergenzschwierigkeiten in der Theorie der Elementarteilchen zeigen, daß die zukünftige Theorie in ihren Grundlagen eine universelle Konstante von der Dimension einer Länge enthalten wird, die in die bisherige Form der Theorie offenbar nicht widerspruchsfrei eingebaut werden kann. Im Hinblick auf diese spätere Abänderung der Theorie versucht die vorliegende Arbeit, aus dem Begriffsgebäude der Quantentheorie der Wellenfelder diejenigen Begriffe herauszuschälen, die von der zukünftigen Änderung wahrscheinlich nicht betroffen werden und die daher einen Bestandteil auch der zukünftigen Theorie bilden werden. Die Arbeit gliedert sich in folgende Abschnitte: I. Die beobachtbaren Größen und ihre mathematische Darstellung. a) Formulierung der Grundannahmen. b) Die mathematische Darstellung der beobachtbaren Größen. c) Die Singularitäten im Impulsraum. d) Die charakteristische Matrix. e) Die Emission mehrerer Teilchen. — II. Die Eigenschaften der Matrix *S*. a) Die allgemeinen quantenmechanischen Eigenschaften von *S*. b) Die singulären Teile der Matrix *S*. c) Berücksichtigung von Spin und Statistik der verschiedenen Elementarteilchen. d) Das relativistische Verhalten der Matrix *S*. — III. Beziehungen zwischen den beobachtbaren Größen. a) Das durch die Matrix *S* gegebene Eigenwertproblem. b) Beziehungen zwischen Streu- und Emissionskoeffizienten. c) Beziehungen zwischen den beobachtbaren Größen, die nicht aus den allgemeinen Eigenschaften der Matrix *S* folgen.

In den vergangenen Jahren ist vielfach[1]) auf die Schwierigkeiten hingewiesen worden, die einer Theorie der Elementarteilchen einstweilen noch im Wege stehen. Diese Schwierigkeiten zeigen sich am auffallendsten in dem Auftreten von Divergenzen (unendliche Selbstenergie des Elektrons, unendliche Polarisation des Vakuums u. dergl.), die den Ausbau einer mathematisch geschlossenen Theorie verhindern, und müssen wohl als Ausdruck der Tatsache aufgefaßt werden, daß bei den in Rede stehenden Erscheinungen eine neue universelle Konstante von der Dimension einer Länge eine entscheidende Rolle spielt, die in den bisherigen Theorien nicht berücksichtigt wird. Einstweilen ist nichts darüber bekannt, welche physi-

*) Herrn Prof. Geiger zum 60. Geburtstage am 30. September 1942 gewidmet.

[1]) Z. B. bei N. Bohr, Kongreß über Kernphysik in Rom 1931, S. 119. V. Weißkopf, ZS. f. Phys. **89**, 27, 1934; A. March, ebenda **104**, 93, 161, 1936; **105**, 620, 1937; G. Wataghin, ebenda **88**, 92; **92**, 547, 1934; W. Heisenberg, Ann. d. Phys. **32**, 20, 1938.

Sonderdruck
aus der „Zeitschrift für Physik" **120**, 673, 1943.
Springer-Verlag, Berlin W 9.

**Die beobachtbaren Größen in der Theorie der Elementarteilchen. II.**

Von **W. Heisenberg** in Berlin,
Max-Planck-Institut der Kaiser Wilhelm-Gesellschaft.

Mit 6 Abbildungen. (Eingegangen am 30. Oktober 1942.)

Im Anschluß an eine frühere Arbeit werden die physikalischen Folgerungen einer Theorie untersucht, in der nicht eine Hamilton-Funktion, sondern die in Teil I erklärte $\eta$-Matrix vorgegeben ist. In dieser Theorie treten im Gegensatz zur üblichen Quantentheorie der Wellenfelder keine Divergenzschwierigkeiten auf und die gestellten Probleme können streng behandelt werden. Die Rechnung wird durchgeführt für die Streuung von Elementarteilchen bei zwei verschiedenen Wechselwirkungsansätzen. Eine $\delta$-funktionsartige Wechselwirkung gibt Resultate, die denen der bisherigen Theorie weitgehend entsprechen. Eine andere, nicht korrespondenzmäßig deutbare Wechselwirkung führt zu Wirkungsquerschnitten, die im Grenzfall großer Energien der stoßenden Teilchen einem endlichen Grenzwert zustreben. Ferner wird die Erzeugung neuer Teilchen an einem Wechselwirkungsansatz untersucht, der die Paarerzeugung enthält. Für kleine Energien der Stoßpartner ergeben sich wieder Resultate, die denen der bisherigen Theorien ähnlich sind, für große Energien treten unter bestimmten Bedingungen explosionsartige Vielfachprozesse auf. Diese Vielfachprozesse werden mathematisch bis in die Einzelheiten diskutiert. Da keine Divergenzschwierigkeiten auftreten, genügen die Ergebnisse auch in Strenge den Forderungen der Relativitätstheorie.

Der in einer früheren Arbeit unternommene Versuch, in der Quantentheorie der Wellenfelder die Größen auszusondern, die als „beobachtbar" auch in der zukünftigen Theorie der Elementarteilchen eine Rolle spielen werden, hat zu folgendem Ergebnis geführt: Die Gesamtheit dessen, was an Streu-, Emissions- und Absorptionsvorgängen im Sinne der genannten Arbeit „beobachtbar" ist, läßt sich zusammenfassen in eine unitäre Matrix *S*. Das Absolutquadrat des Matrixelementes von *S*, das zum Übergang etwa vom Zustand *A* nach dem Zustand *B* gehört, gibt die Wahrscheinlichkeit dafür an, daß der Zustand *B* in der auslaufenden Welle angetroffen wird, wenn der Zustand *A* in der einlaufenden Welle realisiert ist. Die unitäre Matrix *S* hängt mit einer hermitischen Matrix $\eta$ zusammen durch die Gleichung

$$S = e^{i\eta}. \quad (1)$$

Die Eigenwerte von $\eta$ sind die Phasendifferenzen zwischen ein- und auslaufenden Wellen. Die Matrix $\eta$ ist eine relativistische Invariante. Die Folgerungen aus dieser Feststellung für die einzelnen Matrixelemente von $\eta$ sind im Teil I auseinandergesetzt worden. Wenn die Wechselwirkungsenergie

Zeitschrift für Physik. Bd. 120. 45

## *Heisenberg's S-Matrix Theory—Presentation Copy*

**131. Heisenberg, Werner** (1901-76). Die "beobachtbaren Grössen" in der Theorie der Elementarteilchen [parts I – II]. Offprints from *Zeitschrift für Physik* 120 (1943). 513-538; 673-702pp. 230 x 155 mm. Without wrappers. Gatherings of both offprints separated, last leaf of Part I detached, but good to very good. *Heisenberg's Autograph Presentation Inscription* in pencil on the first page of Part I: "Viele herzliche Grüsse! W. H." $7500

**First Editions, Offprint Issues.** The introduction of Heisenberg's S-matrix theory of elementary particles, which he proposed as an alternative to QED. "This paper is remarkable for the number of new ideas it introduces, many of which would be put on a firm mathematical basis only years later. Using a momentum-space representation, [Heisenberg] defined the S-matrix as the coefficient of the outgoing waves in the scattering state . . . This paper contains (in an often symbolic and certainly non-rigorous fashion) the essential elements of formal time-dependent scattering theory, which would later be further developed, for example, by Lippmann and Schwinger (1950), by Gell-Mann and Goldberger (1953) and by Brenig and Haag (1959) . . . Heisenberg certainly brought the concept of the S-matrix to the attention of theoretical physicists. It has remained one of the central tools of modern physics" (Cushing, p. 113). Although Heisenberg's S-matrix theory did not end up replacing QED, it became very influential in the 1960s when it led to the development of string theory, which remains the best-accepted approach to quantum gravity.

A third part of Heisenberg's paper, studying the S-matrix's properties as an "analytic" function, was published in 1944; a fourth part, written at the end of the war, remained unpublished. Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg*, pp. 477-478. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings*, 1943a, 1943b. Cushing, "The importance of Heisenberg's S-matrix program for the theoretical high-energy physics of the 1950s," *Centaurus* 29 (1986): 110-149. 45917

**132. Heisenberg, Werner** (1901-76). Der mathematischen Rahmen der Quantentheorie der Wellenfelder. Offprint from *Zeitschrift für Naturforschung*1 (1946). 608-622pp. 264 x 201 mm. Without wrappers as issued. Creased vertically, paper backstrip worn and separating, some toning and wear. Good to very good. From the library of H. A. Kramers, with his stamp on the first page. $1250

**First Edition, Offprint Issue.** On the mathematical framework of the quantum theory of wave fields. From the library of H. A. Kramers, one of the major contributors to quantum theory. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1946a. 50900

**133. Heisenberg, Werner** (1901-76). Der unanschauliche Quantensprung. In *Neue physikalische Blätter* 1 (1946): 4-6. Whole number. 207 x 148 mm. Original printed wrappers. Light toning but very good. $450

**First Edition,** journal issue. Article on "the inexplicable quantum leap." Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1946b. 50912

**134. Heisenberg, Werner** (1901-76). Zur Theorie der Supraleitung. Offprint from *Zeitschrift für Naturforschung* 2a (1947). 185-201pp. 266 x 203 mm. Without wrappers as issued. Paper backstrip worn and partly detached, vertically creased, some toning, edges frayed. Good copy. From the library of H. A. Kramers, with his stamp on the first page. $850

**First Edition, Offprint Issue.** After the war Heisenberg began investigating superconductivity, the property of certain materials to conduct direct current (DC) electricity without energy loss when they are cooled below a critical temperature. This copy of Heisenberg's paper is from the library of H. A. Kramers, one of the major contributors to quantum theory. Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1947a. 50901

**135. Heisenberg, Werner** (1901-76). Thermodynamische Betrachtungen zum Problem der Supraleitung. Offprint from *Annalen der Physik*, 6$^{th}$ series, 3 (1948). 2589-296pp. 236 x 154 mm. Without wrappers as issued. Moderate toning but very good. $350

**First Edition, Offprint Issue.** Cassidy & Baker, *Werner Heisenberg: A Bibliography of his Writings,* 1948f. 50908

**136. Heisenberg, Werner** (1901-76). Research in Germany on the technical application of atomic energy. Offprint from *Nature* 160 (1947). 10, [1]pp. 212 x 145 mm. Without wrappers as issued. Fine copy. $2750

**First Edition in English, Offprint Issue**. During World War II Heisenberg was one of the principal scientists leading research and development in Germany's nuclear energy program. At that time the Allies had no idea of how far Germany had progressed in the quest to build a nuclear reactor, but given Germany's leading role in the advancement of nuclear physics they had every reason to believe that the Nazis were ahead of the game—in fact, the fear of a German "atom bomb" was one of the main reasons behind the establishment of the Manhattan Project. This fear turned out to be groundless: Due to a combination of factors, including Hitler's dislike of "Jewish science" and the "White Jew" Heisenberg, Germany had fallen far behind the United States in the development of nuclear energy.

After the bombing of Hiroshima Heisenberg became one of the primary crafters of Germany's official account of its wartime nuclear energy program. In December 1946 he published his first postwar summary of the program in the journal *Naturwissenschaften*; the present English translation, slightly abridged from the German, appeared in *Nature* the following August. In the summary Heisenberg argued that Germany's failure to advance its nuclear program was due both to enormous technical difficulties and to the lack of political and financial support; he also played up his own role in slowing down the project by quashing Nazi officials' hopes for the imminent development of atomic weapons. "Heisenberg's self-serving account parallels but overinterprets actual events. He especially did try to maintain scientific control over the [nuclear energy] project. He was also aware of the theoretical possibility of a nuclear explosive by late 1941, he did not demand a crash research and development to build one, and he did seem content to work for the rest of the war on the more modest program of building a reactor. It is difficult to assess his intentions and motives beyond that. But from what we know of his activities and research, there is nothing to support the notion that Heisenberg actually hindered the project in any way to keep an explosive out of Hitler's hands or even that he himself had that much control of the situation" (Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg,* p. 510). Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1947h. 43266

**137. Heisenberg, Werner** (1901-76). Zur Frage der Kausalität in der Quantentheorie der Elementarteilchen. Offprint from *Zeitschrift für Naturforschung* 6a (1951). 281-284pp. 262 x 200 mm. Bifolium; without wrappers as issued. A few marginal tears, light spotting and wear. Good to very good. $350

**First Edition, Offprint Issue.** On the question of causality in the quantum theory of elementary particles. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1951a. 50909

**138. Heisenberg, Werner** (1901-76). Paradoxien des Zeitbegriffs in der Theorie der Elementarteilchen. Offprint from *Festschrift zur Feier des zweihundertjährigen Bestehens der Akademie der Wissenschaft in Göttingen* 1 (Mathematisch-physikalische Klasse) (1951). 50-64pp. 248 x 166mm. Without wrappers as issued. Very good. $350

**First Edition, Offprint Issue.** On time paradoxes in the theory of elementary particles. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1951c. 50907

**139. Heisenberg, Werner** (1901-76). On the mathematical frame of the theory of elementary particles. Offprint from *Communications on Pure and Applied Mathematics* 4 (1951). 15-22pp. 254 x 176 mm. Original printed wrappers, slightly creased. Very good. $350

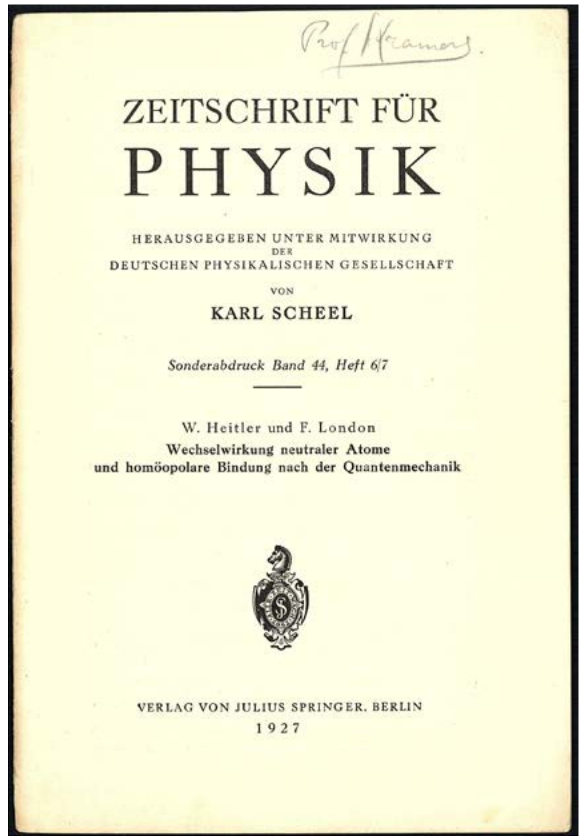
**First Edition, Offprint Issue.** Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1951d. 50904

**140. Heisenberg, Werner** (1901-76). 50 Jahre Quantentheorie. Offprint from *Die Naturwissenschaften* 3 (1951). 49-55pp. 298 x 212 mm. Without wrappers as issued. Creased horizontally, light soiling. Very good. $250

**First Edition, Offprint Issue.** Lecture deliveredon 23 October 1950 at the 96th meeting of the Gesellschaft Deutscher Naturforscher und Ärzte. Cassidy & Baker, W*erner Heisenberg: A Bibliography of his Writings,* 1951h. 50899

## *Valence Bonding*

**141. Heitler, Walter** (1904-81) and **Fritz London** (1900-1954). Wechselwirkung neutraler Atome und homöopolare Bindung nach der Quantenmechanik. Offprint from *Zeitschrift für Physik* 44 (1927). 455-472pp. 230 x 156 mm. Original printed wrappers, small rust-stains on back wrapper. Very good. From the library of H. A. Kramers, with "Prof. Kramers" written in pencil on the front wrapper. $7500



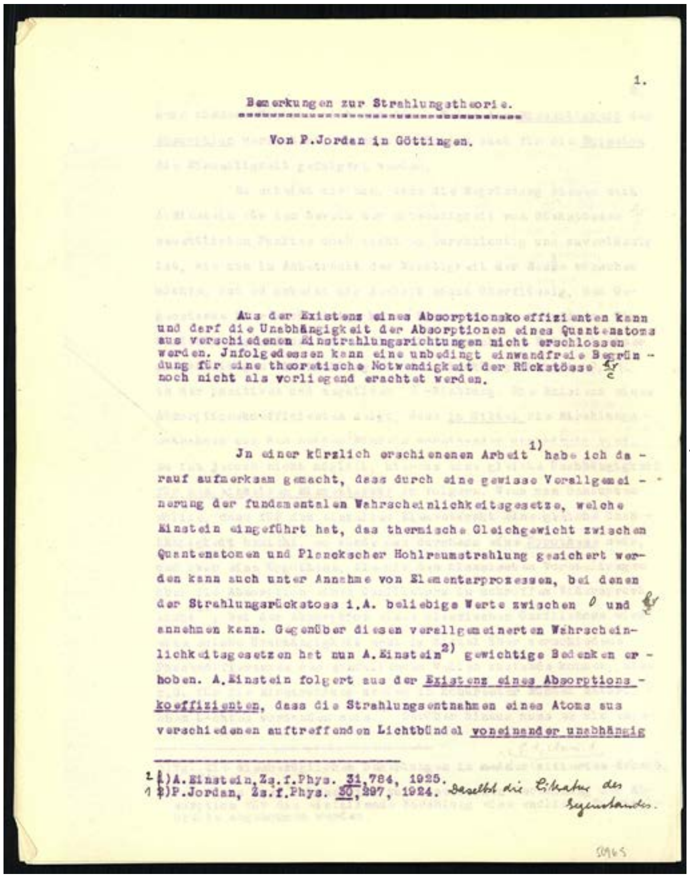

**First Edition, Offprint Issue** of the paper announcing the Heitler-London theory of valence bonding, one of the two basic theories (the other being molecular orbital theory) developed to use the methods of quantum mechanics to explain chemical bonding.

Heitler and London, both students of Schrödinger at the time, joined forces in 1927 to solve the problem of determining the forces between two atoms, at first with disappointing results. The breakthrough came a few weeks later, during a hot windy day, as Heitler later recalled:

> I couldn't do work at all, had a quick lunch, went to sleep again in the afternoon and slept until five o'clock. When I woke up . . . I had clearly . . . the picture before me of the two wave functions of two hydrogen molecules joined together with a plus and minus and with the exchange in it . . . As soon as I was clear that the exchange did play a role, I called London up, and he came to me as quickly as possible. Meanwhile I had already started developing a sort of perturbation theory. We worked together then until rather late at night, and then by that time most of the paper was clear . . . at least it was not later than the following day that we had the formation of the hydrogen molecule in our hand, and we also knew that there was a second mode of interaction which meant repulsion between two hydrogen atoms—also new at the time—new to the chemists, too (quoted in Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, p. 542).

Linus Pauling, who won the 1954 Nobel Prize in chemistry for his research into the nature of the chemical bond, called Heitler and London's paper "the greatest single contribution to the clarification of the chemist's conception which has been made since G. N. Lewis's suggestion in 1916 that the chemical bond between two atoms consists of a pair of electrons held jointly by the two atoms" (quoted in Mehra & Rechenberg, 6, p. 542). Wikipedia Timeline of Quantum Mechanics. 46007

**142. Jordan, Pascual** (1902-80). Bemerkungen zur Strahlungstheorie. Carbon typescript in German, with manuscript additions. 6ff. N.p., n.d. [1925]. 286 x 225 mm. Creased horizontally, edges a bit crinkled, but very good. $7500



1.

Bemerkungen zur Strahlungstheorie.

Von P.Jordan in Göttingen.

Aus der Existenz eines Absorptionskoeffizienten kann und darf die Unabhängigkeit der Absorptionen eines Quantenatoms aus verschiedenen Einstrahlungsrichtungen nicht erschlossen werden. Infolgedessen kann eine unbedingt einwandfreie Begründung für eine theoretische Notwendigkeit der Rückstösse $\frac{h\nu}{c}$ noch nicht als vorliegend erachtet werden.

Jn einer kürzlich erschienenen Arbeit[1] habe ich darauf aufmerksam gemacht, dass durch eine gewisse Verallgemeinerung der fundamentalen Wahrscheinlichkeitsgesetze, welche Einstein eingeführt hat, das thermische Gleichgewicht zwischen Quantenatomen und Planckscher Hohlraumstrahlung gesichert werden kann auch unter Annahme von Elementarprozessen, bei denen der Strahlungsrückstoss i.A. beliebige Werte zwischen $0$ und $\frac{h\nu}{c}$ annehmen kann. Gegenüber diesen verallgemeinerten Wahrscheinlichkeitsgesetzen hat nun A.Einstein[2] gewichtige Bedenken erhoben. A.Einstein folgert aus der Existenz eines Absorptionskoeffizienten, dass die Strahlungsentnahmen eines Atoms aus verschiedenen auftreffenden Lichtbündel voneinander unabhängig

2) A.Einstein, Zs.f.Phys. 31,784, 1925.
1) P.Jordan, Zs.f.Phys. 30,297, 1924. Daselbst die Literatur des Gegenstandes.

**Apparently Unpublished Paper** written in response to Einstein's "Bemerkung zu P. Jordans Abhandlung: 'Zur Theorie der Quantenstrahlung'" (*Zeitschrift für Physik* 31 [March 1925]: 784-785). We can find no evidence that Jordan's paper appeared in any journal, and this typescript copy, with formulae and other additions in Jordan's hand, may be the only copy in existence.

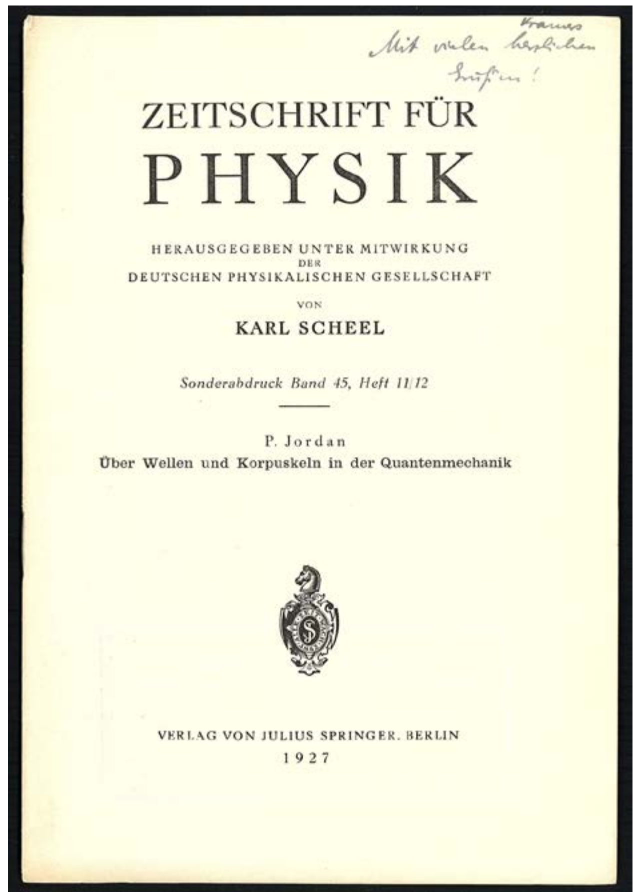
Jordan, one of the authors of the famous *Dreimännerarbeit* on quantum matrix mechanics, obtained his doctorate in physics from Göttingen in 1924 with a thesis on the light-quantum problem, which was published in the *Zeitschrift für Physik* under the title "Zur Theorie der Quantenstrahlung" (*Z. Phys.* 30 [December 1924]: 297-319). At that time Bohr and other quantum physicists had raised a number of objections to Einstein's old conception of light quanta, particularly with regard to the Compton effect, as they could not find a satisfactory way to integrate Einsteinian light quanta into the current quantum physics. In his thesis Jordan addressed this problem, seeking "to propose a compromise between the extreme positions of the light-quantum theory, as assumed by Einstein, and of the wave theory of radiation, as preferred by Niels Bohr on the basis of correspondence arguments. In particular, he made an attempt to modify Einstein's theory of the interaction between electrons or atoms and radiation by avoiding an important assumption of the light-quantum theory: namely, the assumption that a light-quantum of energy $h\nu$ necessarily imparts a recoil momentum of magnitude $h\nu/c$ to the electron or atom" (Mehra & Rechenberg, *The Historical Development of Quantum Theory*, 3, p. 51).

Jordan's proposal did not convince his fellow physicists, particularly Einstein, who summarized his objections in the above-referenced "Bemerkung zu P. Jordans Abhandlung: 'Zur Theorie der Quantenstrahlung'" [Comment on P. Jordan's paper: "On the theory of quantum radiation"]. Jordan's reaction to Einstein's critique can be seen in the present typescript, which begins [English translation ours]:

> In a recently published work I pointed out that by a certain generalization of the fundamental probability laws introduced by Einstein, the thermal equilibrium between quantum atoms and Planckian cavity radiation can also be secured under the assumption of elementary processes in which the radiative recoil can be assigned any values can assume between 0 and $h\nu/c$. A. Einstein raised serious concerns about these generalized probability laws. A. Einstein concludes from the existence of an absorption coefficient that the radiation extraction of an atom from different incident light beams must be independent of each other. If one has assured oneself in this way of the one-sidedness of the absorption, one-sidedness must of course also be concluded for the emission.
>
> It now seems to me that the justification of this point, which according to A. Einstein is essential for the proof of the necessity of recoils $h\nu/c$, is not as transparent and reliable as one would like in view of the importance of the matter, and it seems to me therefore not superfluous to devote a few more brief considerations to the subject here. . .

We do not know why Jordan chose not to publish this paper, but we do know that he did not persist in maintaining his radiation thesis—in his next paper on the subject, published the following August, he followed Pauli's, Einstein's and Ehrenfests's treatments of the processes involved (Mehra & Rechenberg, p. 52). 50965

## *Inscribed by Jordan to Kramers*


Kramers
Mit vielen herzlichen Grüßen!

ZEITSCHRIFT FÜR
PHYSIK
HERAUSGEGEBEN UNTER MITWIRKUNG
DER
DEUTSCHEN PHYSIKALISCHEN GESELLSCHAFT
VON
KARL SCHEEL

Sonderabdruck Band 45, Heft 11/12

P. Jordan
Über Wellen und Korpuskeln in der Quantenmechanik

VERLAG VON JULIUS SPRINGER. BERLIN
1927

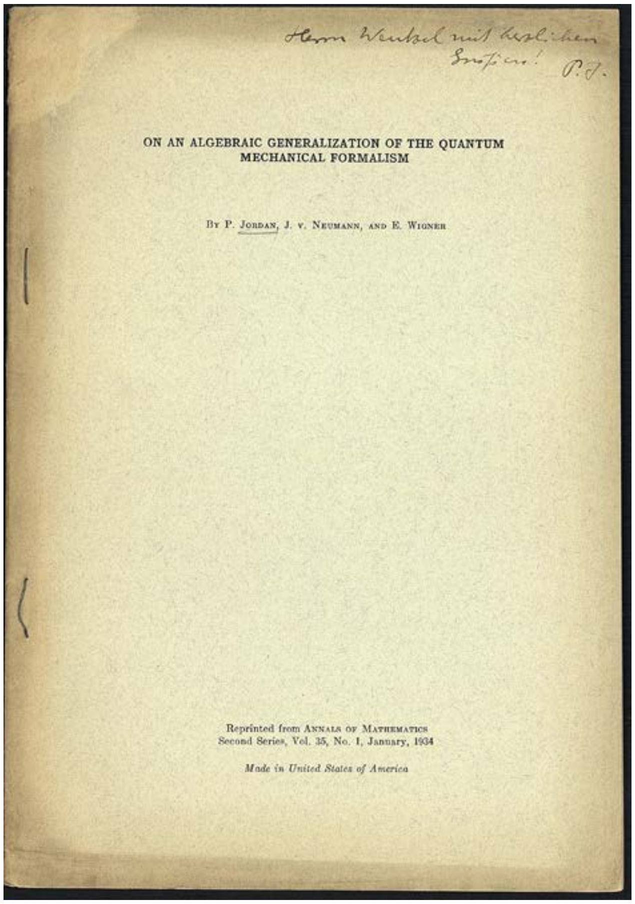
**143. Jordan, Pascual** (1902-80). Über Wellen und Korpuskeln in der Quantenmechanik. Offprint from *Zeitschrift für Physik* 45 (1927). 766-775pp. 229 x 157 mm. Original printed wrappers, slightly toned. Very good. Presentation Copy, inscribed by Jordan to H. A. Kramers (1894-1952) on the front wrapper: "Kramers Mit vielen herzlichen Grüßen!" [Kramers with best regards]. $3500

**First Edition, Offprint Issue.** Jordan, the "unsung hero among the creators of quantum mechanics" (Schweber, *QED and the Men who Made It*, p. 5), was one of the founders of quantum electrodynamics. In 1927 Dirac had laid out the initial formulation of QED in his paper "The quantum theory of emission and absorption of radiation," which introduced the idea of "second quantization" to reconcile the wave and light-quantum descriptions of the electromagnetic field. "Reading Dirac's QED paper gave Jordan the insight on how to 'second quantize' so that the quanta obeyed the Pauli exclusion principle" (Schweber, p. 34).

For Jordan, this second quantization "was to be viewed as the quantization of a classical field. Jordan had been very much drawn to the de Broglie-Einstein-Schrödinger view that fields were the primary entities. Moreover, he believed that this procedure should be applied to matter fields in the same way as it had been applied by him to the electromagnetic field in his paper with Born (1926) and in the Dreimännerarbeit (1926) . . . In a series of seminal papers [including this one] stimulated by Dirac's formulation, Jordan established that the 'second quantization' procedure could in fact be thus interpreted. These papers laid the foundation of quantum field theory" (Schweber, p. 33; emphasis ours).

Following a joint paper with Oskar Klein ("Zum Mehrkörperproblem der Quantentheorie," 1927), Jordan published the present paper in which he formulated the quantization rules to yield Fermi-Dirac statistics. This paper "contained several other formal and mathematical generalizations, but its main practical value is that, in the newly established theory of the 'quantized wave field,' the fluctuations in the Bose case now satisfied all requirements following from Einstein's light-quantum treatment of 1924 and 1925" (Mehra and Rechenberg, *Historical Development of Quantum Theory*, 6, p. 231). 46050

**144. Jordan, Pascual** (1902-80); **John von Neumann** (1903-57); and **Eugene Wigner** (1902-95). On an algebraic generalization of the quantum mechanical formalism. Offprint from *Annals of Mathematics*, second series, 35 (1934). 29-64pp. 254 x 176 mm. Original printed wrappers, margins a bit dust-soiled. Very good. *Presentation Copy, Inscribed by Jordan to physicist Gregor Wentzel* (1898-1978) on the front wrapper: "Herrn Wentzel mit hertzlichen Grüssen! P. J." $2750




**First Edition, Offprint Issue** of Jordan, von Neumann and Wigner's classic paper on one of the mathematical foundations of quantum mechanics, introducing what are now known as the formally real Jordan algebras. "When [the real numbers, the complex numbers and the quaternions] were sent down from platonic heaven to tell the world about the algebraic structure of quantum mechanics, they took on human avatars and wrote this paper" (Baez).

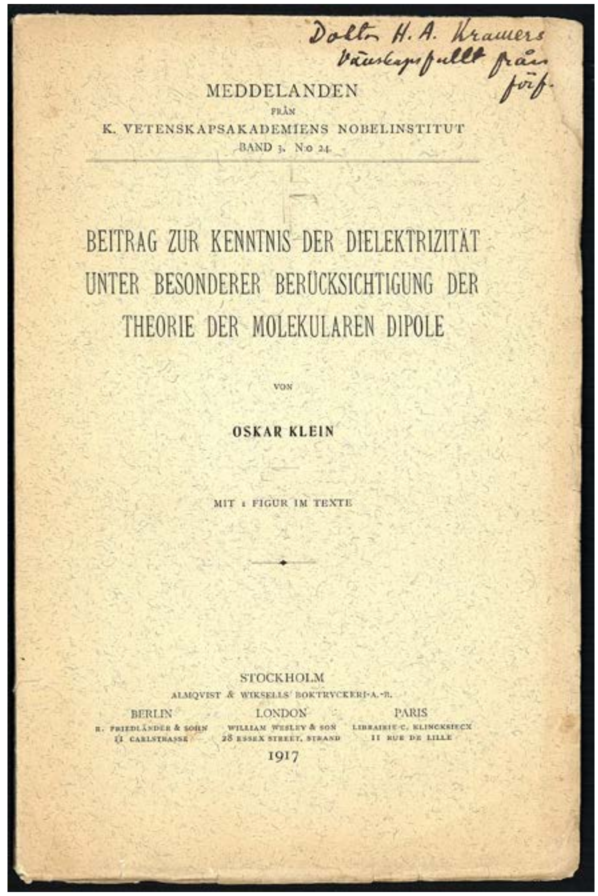
In an earlier paper Jordan had introduced the "Jordan algebras," a special type of non-associative algebra, to formalize the notion of an algebra of observables in quantum mechanics.

> In 1932, Pascual Jordan tried to isolate some axioms that an "algebra of observables" should satisfy. The unadorned phrase "algebra" usually signals an associative algebra [i.e., one in which $(a + b) + c = a + (b + c)$], but this not the kind of algebra Jordan was led to. In both classical and quantum mechanics, observables are closed under addition and multiplication by real scalars. In classical mechanics we can also multiply observables, but in quantum mechanics this becomes problematic. . . .
>
> However, in quantum mechanics one can still raise an observable to a power and obtain another observable. From squaring and taking real linear combinations, one can construct a commutative product . . . This led Jordan to define what is now called a formally real Jordan algebra . . . **In 1934, Jordan published a paper with von Neumann and Wigner classifying finite-dimensional formally real Jordan algebras** (Baez; emphasis ours).

The formally real Jordan algebras correspond to various spin factors, which in turn "have an intriguing relation to special relativity" (Baez). Jordan algebras also play important roles in other branches of mathematics: Lie groups and algebras, differential geometry, projective geometry, probability and statistics.

Jordan presented this copy of his paper to theoretical physicist Gregor Wentzel, who also made contributions to quantum mechanics: He is best known for the Wentzel-Kramers-Brillouin approximation for finding approximate solutions to linear partial differential equations with spatially varying coefficients. Baez, John, "State-Observable Duality (Part 2)." *The N-category Cafe: A Group Blog on Math, Physics and Philosophy.* N.p., 27 Nov. 2010. Web. Accessed 12 Sept. 2014. 43272

**145. Klein, Oskar** (1894-1977). Beitrag zur Kenntnis der Dielektrizität unter besonderer Berücksichtigung der Theorie der molekularen Dipole. Offprint from *Meddelanden från K. Vetenskapsakademiens Nobelinstitut* 3 (1917). 48pp. 226 x 150 mm. Original printed wrappers, edges a bit frayed, small waterstain in upper right corner. Very good. *Presentation Copy,* inscribed by Klein to H. A. Kramers (1894-1952) on the front wrapper: "Doctor H. A. Kramers väuskapsfullt från förf." $2750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FRÅN
K. VETENSKAPSAKADEMIENS NOBELINSTITUT
BAND 3. N:o 24.

BEITRAG ZUR KENNTNIS DER DIELEKTRIZITÄT UNTER BESONDERER BERÜCKSICHTIGUNG DER THEORIE DER MOLEKULAREN DIPOLE

VON

OSKAR KLEIN

MIT 1 FIGUR IM TEXTE

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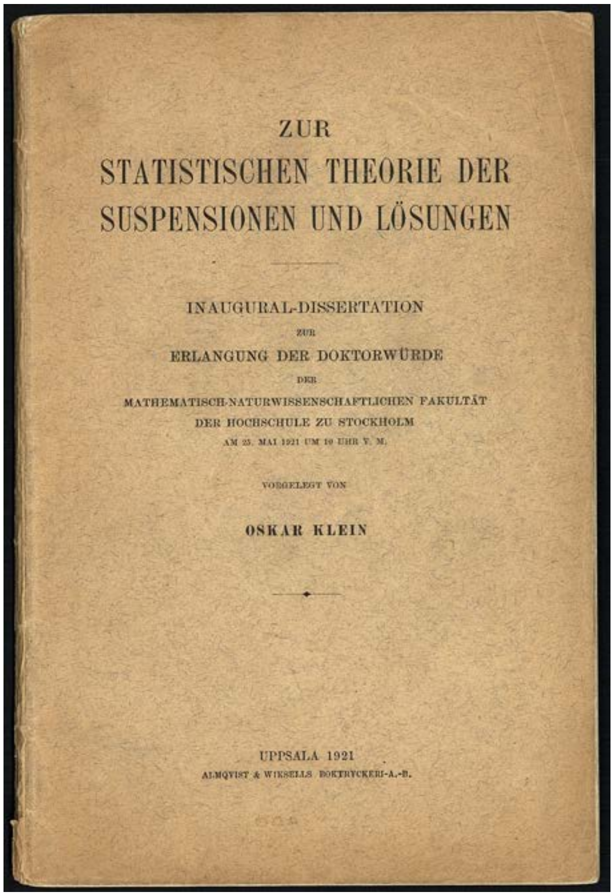
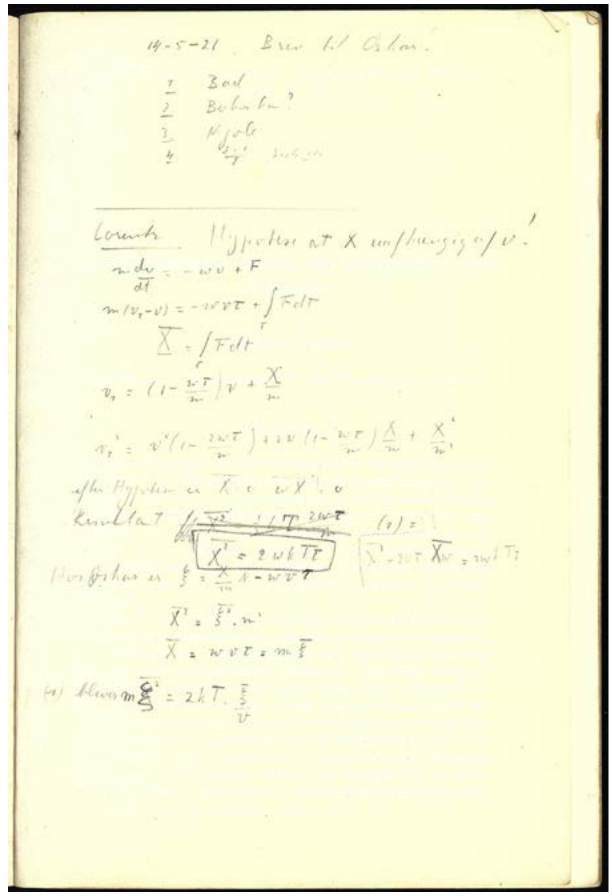
1917

**First Edition, Offprint Issue.** Klein, a Swedish theoretical physicist, is best known for the Klein-Gordon relativistic wave equation, the Klein-Nishina formula for Compton scattering from atomic electrons—one of the first results obtained from the study of quantum electrodynamics—and for the Kaluza-Klein theory, a classical unified field theory of gravitation and electromagnetism built around the idea of a fifth dimension. During the early 1920s he worked at Niels Bohr's Institute for Theoretical Physics in Copenhagen, where he and H. A. Kramers became Bohr's closest collaborators. After spending a few years teaching at the University of Michigan, Klein returned to Europe in 1925, eventually accepting the professorial chair in physics at Stockholm University. He remained at the university until his retirement in 1962. While Klein was a student he worked as a scientific assistant at the Nobel Institute in Stockholm, where between 1917 and 1919 he published three papers on the dielectric properties of dipolar molecules and on electrolytes. The title of the present paper translates to "Contribution to the knowledge of dielectricity with special reference to the theory of molecular dipoles." Klein presented this copy to Dutch physicist H. A. Kramers, one of the major architects of quantum theory; Kramers and Klein were among Niels Bohr's closest collaborators. 50981

**146. Klein, Oskar** (1894-1977). Calculation of scattered radiation from a plate exposed to a beam of X-rays. Offprint from *The Philosophical Magazine* 37 (1919). 207-214pp. 222 x 146 mm. Original plain wrappers, stitching loose, slightly sunned. Very good. *Presentation Copy,* inscribed by Klein to H. A. Kramers (1894-1953) on the front wrapper: "Hans Kramers från vaunen förf." $1500

**First Edition, Offprint Issue.** 50982





## *Interleaved Copy of Klein's Ph.D. Thesis with Numerous Annotations in Danish*

**147. Klein, Oskar** (1894-1977). Zur statistischen Theorie der Suspension und Lösungen. Inaugural-Dissertation . . . *Arkiv för Matematik, Astronomi och Fysik* 16, no. 5. 51pp. plus interleaves. Uppsala: Almqvist & Wiksells, 1921. 219 x 146 mm. Original printed wrappers, a bit soiled, light wear to spine. Very good. *Author's interleaved copy,* with numerous equations, notes and corrections in Danish in pencil and ink on the interleaves. $5000

**First Edition** of Klein's dissertation for his doctorate in physics from Stockholm University, in which "he presented an important study of the statistical theory of suspensions and solutions based on Josiah Willard Gibbs's statistical methods" (*Dictionary of Scientific Biography*). Klein presented his dissertation on 13 April 1921; it was printed on 9 May.

This interleaved copy contains numerous manuscript annotations, equations and remarks in Danish on the interleaves; although the notes are unsigned, the handwriting bears more than a passing resemblance to that of Niels Bohr. It is certainly plausible that Klein would send a copy of his thesis to Bohr upon its publication: Klein worked under Bohr at the Institute for Theoretical Physics during his student years, and would later become one of his closest collaborators. On the other hand, it is less likely that Klein would send Bohr any of his papers without first inscribing them to his honored teacher. The first interleaf in this copy is headed "14-5-21 Brev til Oskar!" [14 May 1921 Letter to Oskar!] and another interleaf following p. 50 is headed "25/5/21"; this indicates that whoever annotated Klein's thesis was doing so shortly after its publication. 50983

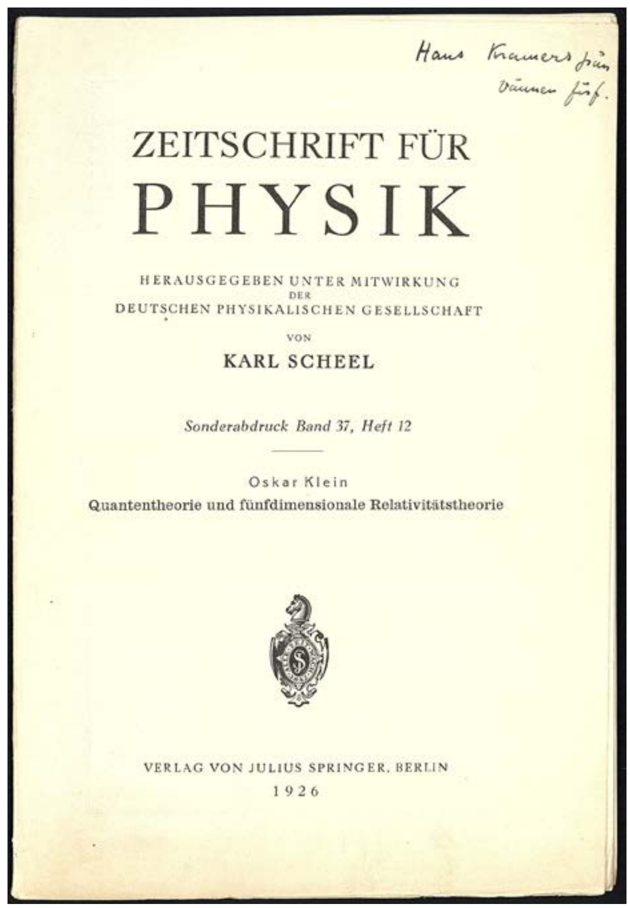
**148. Klein, Oskar** (1894-1977). Über die gleichzeitige Wirkung von gekreuzten homogenen elektrischen und magnetischen Feldern auf das Wasserstoffatom. I [all published]. Offprint from *Zeitschrift für Physik* 22 (1924). 109-118pp. 229 x 155 mm. Original printed wrappers, slightly toned. Very good. From the library of H. A. Kramers (1894-1952), with his pencil signature on the front wrapper. $1750

**First Edition, Offprint Issue** of Klein's paper exposing a fundamental difficulty with pre-1925 quantum theory. This copy is from the library of H. A. Kramers, one of the major architects of quantum theory.

In September 1923 Klein joined the faculty of the University of Michigan in Ann Arbor, where he worked with spectroscopist Harrison M. Randall to build up the university's physics department; he remained at the university until the summer of 1925. "There was a special interest in molecular spectra at Ann Arbor. Randall had been working with Friedrich Paschen at Tübingen participating in these activities. Klein studied molecular interactions in terms of perturbation methods used by Bohr for the Stark effect. The outcome was [the present] paper on the simultaneous action on a hydrogen atom of crossed homogeneous electric and magnetic fields, which revealed a fundamental difficulty of the older quantum theory: that in this situation, transitions became possible from 'allowed' to 'prohibited' orbits. In his review of the state of quantum theory in 1925 (1926), Wolfgang Pauli concluded that this difficulty could be avoided only by a fundamental revision of the basic principles" (*Dictionary of Scientific Biography*). The second part of Klein's paper was never published. 50984

## *Kaluza-Klein Theory—The Fifth Dimension*

**149. Klein, Oskar** (1894-1977). Quantentheorie und fünfdimensionale Relativitätstheorie. Offprint from *Zeitschrift für Physik* 37 (1926). 895-906pp. 229 x 157 mm. Original printed wrappers, slightly worn. Very good. *Presentation Copy,* inscribed by Klein to H. A. Kramers (1894-1952) on the front wrapper: "Hans Kramers från vännen förf." [Hans Kramers from his friend the author]. $4500




**First Edition, Offprint Issue.** In 1921 Theodor Kaluza published a paper in which he showed how to unify Einstein's gravitational equations with electromagnetism by introducing a fifth dimension. Five years later, in the present paper, Klein gave Kaluza's classical theory a quantum interpretation in light of the recently introduced quantum mechanics of Heisenberg and Schrödinger. "He did this by the simple device of assuming that the topology of the extra dimension was not flat and open, but curved in a circle . . . This cyclic behavior would lead to quantum effects, provided the extra dimension were rolled up to a microscopic size ("compactification"). The size of the extra dimension was presumed to be related to the parameter typical of quantum phenomena, namely Planck's constant *h*. Among the other consequences of the closed topology of the extra dimension, it was shown that the cyclic momentum could be related to the charge of the electron *e*, thus explaining its quantization" (Wesson, pp. 4-5). Kaluza-Klein theory is the ancestor of modern induced-matter and membrane theory, and was an important precursor to string theory. P. Wesson, *Five-Dimensional Physics: Classical and Quantum Consequences of Kaluza-Klein Cosmology* (2006). 46037

**150. Klein, Oskar** (1894-1977). Elektrodynamik und Wellenmechanik vom Standpunkt des Korrespondenzprinzips. Offprint from *Zeitschrift für Physik* 41 (1927). 407-442pp. 230 x 157 mm. Original printed wrappers, a bit soiled, small marginal tears, spine worn. Very good. *Presentation Copy,* inscribed by Klein to H. A. Kramers (1894-1952) on the front wrapper: "Professor H. A. Kramers med vauligaste hälsningur från förf." $2750

**First Edition, Offprint Issue.** "During 1926 Klein became deeply involved in Bohr's work on correspondence and complementarity, which evolved into the Copenhagen interpretation of the quantum theory, offering a unified conception of the particle and wave character of microparticles. He obtained [in the present paper] a relativistic extension of Schrödinger's expressions for the electric charge and current density associated with the wave field. **The point of view of correspondence allowed him to establish a rule to determine the atomic transition probabilities before Dirac did so** in a more satisfactory way by quantization of the electromagnetic field. However, Klein's procedure remained accepted for many years" (*Dictionary of Scientific Biography*; emphasis ours).

Klein presented this copy to Dutch physicist H. A. Kramers, one of the major architects of quantum theory; Kramers and Klein were among Bohr's closest collaborators. 50980

## *Klein Paradox*

**151. Klein, Oskar** (1894-1977). Die Reflexion von Elektronen an einem Potentialsprung nach der relativistischen Dynamik von Dirac. Offprint from *Zeitschrift für Physik* 53 (1929). 157-165pp. 229 x 156 mm. Original printed wrappers, slightly creased, light wear. Very good. H. A. Kramers' copy, with his pencil signature on the front wrapper. $3500

**First Edition, Offprint Issue** of the paper that introduced "Klein's paradox," which represented a major barrier to understanding the behavior of the electron in Dirac's relativistic dynamics. "This paradox may be formulated as follows: How can an electron be confined within a nuclear potential well if, as follows from the Dirac equation of the electron, any electron of sufficiently high energy impinging upon a high and steeply rising potential barrier has a high probability of escaping simply by being transformed from a particle of positive mass into one of negative mass?" (Stuewer, p. 199). Klein's paradox presented a quantum-mechanical objection to the notion of an electron confined within an atomic nucleus, thus exposing a critical problem in the then-accepted proton-electron model of the nucleus. The meaning of Klein's paradox was intensely debated by Bohr and others; it "posed a serious problem of understanding in the following years, until it found a solution in the substantially new interpretation of negative-energy states in the Dirac equation as antiparticles of the electron" (Mehra & Rechenberg, *Historical Development of Quantum Theory,* 6, p. 311). R. Stuewer, "Niels Bohr and nuclear physics," in A. P. French and P. J. Kennedy, eds., *Niels Bohr: A Centenary Volume* (1985), pp. 197-220. Wikipedia Timeline of Quantum Mechanics. 46048

**152. Klein, Oskar** (1894-1977). Ein Rekursionsverfahrung zur Lösung der eindimensionalen Wellengleichung der Quantenmechanik. Offprint from *Förhandlingar vid Attonde Skandinaviska Matemetikerkongressen i Stockholm 1934*. Lund: Håkan Olsson, 1935. 243-248pp. 245 x 164 mm. Original printed wrappers, a bit dust-soiled and creased. Very good. $1250

**First Edition, Offprint Issue.** On a recursion method to solve the one-dimensional wave equation of quantum mechanics. 50985

**153. Klein, Oskar** (1894-1977). Den elektriske elementarladning og kvanteteorien. Offprint from *Fysisk Tidsskrift* 33 (1935). 102-109pp. 235 x 158 mm. Original printed wrappers, a bit sunned, corners a little bent. Very good. $750

**First Edition, Offprint Issue.** 50986

**154. Klein, Oskar** (1894-1977). Eine Verallgemeinerung der Diracschen relativistischen Wellengleichung. Offprint from *Arkiv för Matematik, Astronomi och Fysik* 25A (1936). 19pp. 219 x 142 mm. Original printed wrappers, slightly sunned. Very good to fine. *Presentation Copy,* inscribed by Klein to H. A. Kramers (1894-1952) on the front wrapper: "Hans Kramers med hjärtliga hälsningar O. K." $750

**First Edition, Offprint Issue.** On a generalization of Dirac's relativistic wave equation. 50987

**155. Klein, Oskar** (1894-1977). Quelques remarques sur le traitement approximative du problème des électrons dans un réseau cristallin par la mécanique quantique. Offprint from *Journal de physique et le radium* 9 (1938). 12pp. 271 x 220 mm. Original printed wrappers, a bit sunned, creased horizontally and vertically. Very good. *Presentation Copy*, inscribed by the author to H. A. Kramers (1894-1952) on the front wrapper: "Hans Kramers från [illeg.] förf." $1250

**First Edition, Offprint Issue.** "In 1938 [Klein] presented some procedures for solving the Schrödinger equation in a periodic force field and also for describing electron interactions in a crystal" (*Dictionary of Scientific Biography*). Klein presented this copy to Dutch physicist H. A. Kramers, one of the major architects of quantum theory. 50995

**156. Klein, Oskar** (1894-1977) and **J. Runnström.** Considerations on the kinetics of respiration with special reference to the inhibition caused by carbon monoxide. Offprint from *Arkiv för Kemi, Mineralogi och Geologi* 14A (1940). 17pp. 219 x 141 mm. Original printed wrappers, slightly sunned. Fine. $375

**First Edition, Offprint Issue.** 50944

**157. Klein, Oskar** (1894-1977). On the meson pair theory of nuclear interaction. Offprint from *Arkiv för Matematik, Astronomi och Fysik* 30A (1943). 13pp. 218 x 141 mm. Original printed wrappers. Fine. $375

**First Edition, Offprint Issue.** 50993

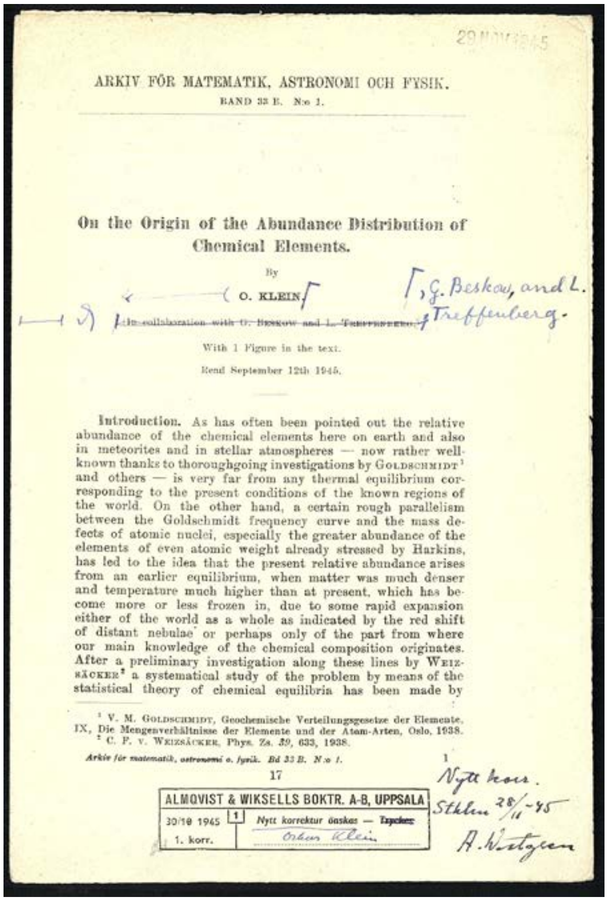
**158. Klein, Oskar** (1894-1977). (1) On the magnetic behaviour of electrons in crystals. Offprint from *Arkiv för Matematik, Astronomi och Fysik* 31A (1944). 15pp. 219 x 141 mm. Original printed wrappers, a bit sunned. (2) On the specific heat of the superconductive state. Offprint from *Arkiv för Matematik, Astronomi och Fysik* 33B (1945). 7pp. 217 x 142 mm. Original plain wrappers, a bit sunned. Together 2 items. Very good to fine. $850

**First Editions, Offprint Issues.** In the 1940s Klein became interested in superconductivity, making important contributions to the subject. In the first paper listed above, "in order to obtain a quantum mechanical microscopic model of [superconductivity], he computed the diamagnetic properties of an electron gas" (*Dictionary of Scientific Biography*). After collaborating with Jens Lindhard on developing a quantum theory of the superconductive state, which the two published in 1945 (not present here), Klein published a paper on the specific heat of the superconductive state (no. [2] above), in which he proposed "a possible explanation of its characteristic features" (p. 1). 50992, 50991

**159. Klein, Oskar** (1894-1977). On the origin of cosmic radiation. Offprint from *Arkiv för Matematik, Astronomi och Fysik* 31A (1944). 9pp. 217 x 141 mm. Original printed wrappers, slightly toned. Fine. $375

**First Edition, Offprint Issue.** 50989

**160. Klein, Oskar** (1894-1977); **Göran Beskov** (1910-2011); and **Lars Treffenberg.** On the origin of the abundance distribution of chemical elements. Corrected galley proofs, with a 16-line addition in Klein's hand on the last page, of the paper published in *Arkiv för Matematik, Astronomi o. Fysik* 33 (1946). N.p., 1945. 7pp. 236 x 157 mm. Horizontally creased, light soiling and wear. Very good. Datestamp (29 Nov 1945) on the first page. $3750


29 NOV 1945

ARKIV FÖR MATEMATIK, ASTRONOMI OCH FYSIK.
BAND 33 B. N:o 1.

On the Origin of the Abundance Distribution of Chemical Elements.

By

O. KLEIN, G. Beskow, and L. Treffenberg.

~~In collaboration with G. Beskow and L. Treffenberg.~~

With 1 Figure in the text.

Read September 12th 1945.

**Introduction.** As has often been pointed out the relative abundance of the chemical elements here on earth and also in meteorites and in stellar atmospheres — now rather well-known thanks to thoroughgoing investigations by Goldschmidt[1] and others — is very far from any thermal equilibrium corresponding to the present conditions of the known regions of the world. On the other hand, a certain rough parallelism between the Goldschmidt frequency curve and the mass defects of atomic nuclei, especially the greater abundance of the elements of even atomic weight already stressed by Harkins, has led to the idea that the present relative abundance arises from an earlier equilibrium, when matter was much denser and temperature much higher than at present, which has become more or less frozen in, due to some rapid expansion either of the world as a whole as indicated by the red shift of distant nebulae or perhaps only of the part from where our main knowledge of the chemical composition originates. After a preliminary investigation along these lines by Weizsäcker[2] a systematical study of the problem by means of the statistical theory of chemical equilibria has been made by

[1] V. M. Goldschmidt, Geochemische Verteilungsgesetze der Elemente, IX, Die Mengenverhältnisse der Elemente und der Atom-Arten, Oslo, 1938.
[2] C. F. v. Weizsäcker, Phys. Zs. 39, 633, 1938.

*Arkiv för matematik, astronomi o. fysik. Bd 33 B. N:o 1.* 1

17

ALMQVIST & WIKSELLS BOKTR. A-B, UPPSALA
30/10 1945 | 1 | Nytt korrektur önskas — ~~Tryckes~~
1. korr. | Oskar Klein

**Pre-Publication Galley Proof, Extensively Corrected and Augmented in Klein's Hand.** "In 1946, with the Swedish physicists Göran Beskov and Lars Treffenberg, Klein published a work on the distribution of chemical elements. They intended to solve the basic problems connected with the so-called hypothesis of frozen equilibrium in accounting for the distribution of the chemical elements" (*Dictionary of Scientific Biography*). As Klein later wrote, he and his collaborators "developed an attempt to explain the relative abundance of the elements as the result of an early thermal equilibrium at very high temperature in a kind of primordial stars. The result looked promising but simultaneously difficulties appeared" (Klein, p. 142). Klein's theory, although ingenious, is not widely accepted.

These galley proofs are date-stamped 29 November 1945, several weeks before the paper appeared in the *Arkiv för Matematik, Astronomi o. Fysik.* On the proofs' first page Klein revised the author statement to give Beskow and Treffenberg equal billing. Klein, "Excerpts from some autobiographical notes," *Oskar Klein Memorial Lectures,* vol. 2, pp. 141-148. 50996

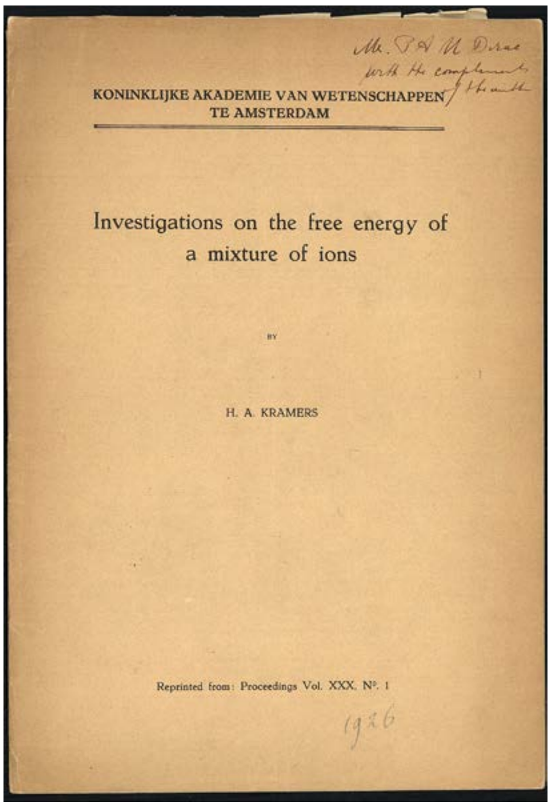
**161. Klein, Oskar** (1894-1977). Meson fields and nuclear interaction. Offprint from *Arkiv för Matematik, Astronomi och Fysik* 34A (1946). 19pp. 217 x 141 mm. Original printed wrappers, slightly sunned, faint creasing. Very good. Notes in English in an unidentified hand, headed "Lecture Brown April 28 '47 / Interaction radiation & matter," on the verso of the last leaf and both sides of the back wrapper. $750

**First Edition, Offprint Issue.** In 1926 Klein made an "elegant attempt" to unify gravity and electromagnetism with his Klein-Kaluza five-dimensional theory. "In 1947 [*sic*] Klein tried to incorporate meson forces into this theory. In order to confine the charge of the mesons to integral positive and negative multiples of the elementary charge, the wave function must be a periodic function of the fifth coordinate, and this periodicity introduced a fundamental length scale into the theory. Klein was the first to recognize the similarity of the newly discovered muon decay to nuclear beta decay. This was the first indication of the universal Fermi interaction for weak interactions" (*Dictionary of Scientific Biography*).

The offprint of Klein's paper was printed on 31 December 1946; the journal article appeared in the 1947-48 volume of the *Arkiv för Matematik, Astronomi och Fysik.* We have not been able to identify the author of the handwritten notes in this copy. 50977

**162. Klein, Oskar** (1894-1977). On a case of radiation equilibrium in general relativity theory and its bearing on the early stage of stellar evolution. Offprint from *Arkiv för Matematik, Astronomi och Fysik* 34A (1947). 11pp. 218 x 141 mm. Original printed wrappers. Fine. "With compliments from the author" stamped on the front wrapper. $450

**First Edition, Offprint Issue.** 50988



Mr. P A M Dirac with the compliments of the author

KONINKLIJKE AKADEMIE VAN WETENSCHAPPEN
TE AMSTERDAM

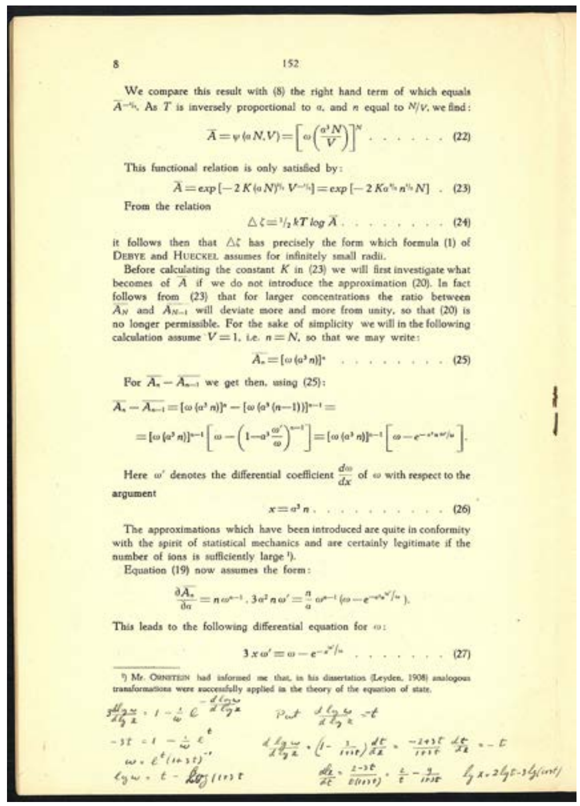
Investigations on the free energy of a mixture of ions

BY

H. A. KRAMERS

Reprinted from: Proceedings Vol. XXX. No. 1

1926



8 152

We compare this result with (8) the right hand term of which equals $\overline{A}^{-1/2}$. As $T$ is inversely proportional to $\alpha$, and $n$ equal to $N/V$, we find:

$$\overline{A} = \psi(\alpha N, V) = \left[\omega\left(\frac{\alpha^3 N}{V}\right)\right]^N \quad (22)$$

This functional relation is only satisfied by:

$$\overline{A} = \exp\left[-2K(\alpha N)^{3/2} V^{-1/2}\right] = \exp\left[-2K\alpha^{3/2} n^{1/2} N\right] \quad (23)$$

From the relation

$$\Delta\zeta = {}^1/_2\, kT \log \overline{A} \quad (24)$$

it follows then that $\Delta\zeta$ has precisely the form which formula (1) of DEBYE and HUECKEL assumes for infinitely small radii.

Before calculating the constant $K$ in (23) we will first investigate what becomes of $\overline{A}$ if we do not introduce the approximation (20). In fact follows from (23) that for larger concentrations the ratio between $\overline{A_N}$ and $\overline{A_{N-1}}$ will deviate more and more from unity, so that (20) is no longer permissible. For the sake of simplicity we will in the following calculation assume $V=1$, i.e. $n=N$, so that we may write:

$$\overline{A_n} = [\omega(\alpha^3 n)]^n \quad (25)$$

For $\overline{A_n} - \overline{A_{n-1}}$ we get then, using (25):

$$\overline{A_n} - \overline{A_{n-1}} = [\omega(\alpha^3 n)]^n - [\omega(\alpha^3(n-1))]^{n-1} =$$

$$= [\omega(\alpha^3 n)]^{n-1}\left[\omega - \left(1 - \alpha^3\frac{\omega'}{\omega}\right)^{n-1}\right] = [\omega(\alpha^3 n)]^{n-1}\left[\omega - e^{-\alpha^3 n\omega'/\omega}\right].$$

Here $\omega'$ denotes the differential coefficient $\frac{d\omega}{dx}$ of $\omega$ with respect to the argument

$$x = \alpha^3 n \quad (26)$$

The approximations which have been introduced are quite in conformity with the spirit of statistical mechanics and are certainly legitimate if the number of ions is sufficiently large [1]).

Equation (19) now assumes the form:

$$\frac{\partial \overline{A_n}}{\partial\alpha} = n\omega^{n-1} \cdot 3\alpha^2 n\omega' = \frac{n}{\alpha}\omega^{n-1}\left(\omega - e^{-x\omega'/\omega}\right).$$

This leads to the following differential equation for $\omega$:

$$3x\omega' = \omega - e^{-x\omega'/\omega} \quad (27)$$

[1]) Mr. ORNSTEIN had informed me that, in his dissertation (Leyden, 1908) analogous transformations were successfully applied in the theory of the equation of state.

## *Inscribed by Kramers to Dirac, and with a Series of Equations in Dirac's Hand*

**163. Kramers, H. A.** (1894-1952). Investigations on the free energy of a mixture of ions. Offprint from *Koninklijke Akademie van Wetenschappen te Amsterdam* 30 (1927). 14pp. 261 x 182 mm. Original printed wrappers, light wear and sunning, small rust stain from paper clip. Very good. *Inscribed by Kramers to Paul Dirac* (1902-84) on the front wrapper: "Mr. P A M Dirac with the compliments of the author." *With a Series of Equations in Dirac's Hand* in the lower margin of page 8. Undated note in pencil to Kramers from American chemist Victor K. La Mer (1895-1966) clipped to the back wrapper. From Kramers's library. $5000

**First Edition, Offprint Issue.** Kramers' first paper on statistical mechanics, in which he shed further light on the Debye-Hückel expression for the free energy of mixtures of ions. Kramers presented this copy of his paper to Paul Dirac, the brilliant English physicist who would later win the Nobel Prize for his relativistic equation of the electron. Sometime later Dirac returned the paper to Kramers, after adding seven lines of his own calculations on page 8. 45914

**164. Kramers, H. A.** (1894-1952). Topics in theoretical physics: Lectures . . . given at the California Institute of Technology May 22 to May 29, 1947. Dittoed typescript. 9, 2, 6 [1]ff. [**Bound with:**] **Brinkman, Henri Coenraad** (1908-61). The quantum mechanics of multipole radiation . . . translated by E. Richard Cohen and Mark M. Mills. Dittoed typescript. [2], 65ff. Together 2 items. 281 x 217 mm. Bound together in stiff folder with metal fasteners, slight edgewear. Very good. Two sheets of manuscript notes on lined yellow paper laid in. $3750

**First Printing,** and *scarce,* with OCLC recording only two copies (both at UCLA). Kramers's 1947 Caltech lectures were on symbolic methods in quantum mechanics, on the transition state method in chemical kinetics, and on the formation of cosmic dust. Kramers had originally intended to give three more lectures on symbolic methods at this time, but was not able to fulfil this plan; instead, he provided his audience with a copy of Henri Brinkman's thesis on the quantum mechanics of multipole radiation, containing "a systematic development of the symbolic methods . . . in place of the more fragmentary lectures that [he] was forced to give" (last leaf of Kramers's lectures). Brinkman was a Dutch mathematician and physicist; the dimensionless "Brinkman number," related to heat conduction from a wall to a flowing viscous fluid, is named for him. 51016

**165. Kramers, H. A.** (1894-1952). Topics in theoretical physics: Lectures . . . given at the California Institute of Technology May 22 to May 29, 1947. Dittoed typescript. 9, 2, 6 [1]ff. 281 x 217 mm. Bound in stiff folder with metal fastenings, light wear. Light marginal soiling and fraying but very good. $2750

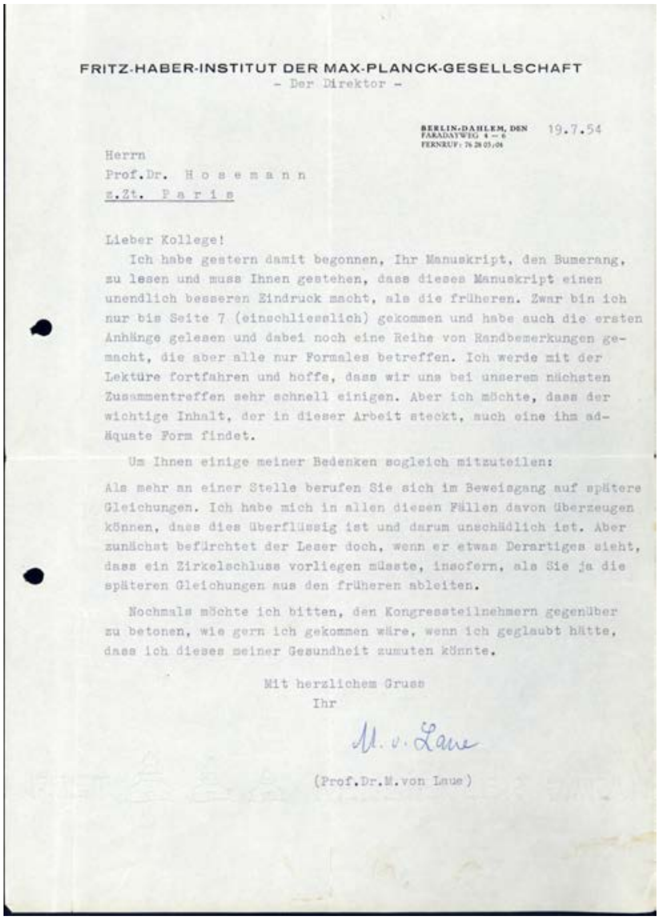
**First Printing.** Same as the above, but without Brinkman's thesis. 51015

**166. Laue, Max von** (1879-1960). Thermodynamische Betrachtungen über Interferenzerscheinungen. Offprint from *Verhandlungen der Deutschen Physikalischen Gesellschaft* 9 (1907). 606-620pp. 232 x 150 mm. Original printed wrappers, two corners a bit creased, small ink stain on front wrapper. Very good. From the library of Henri Becquerel (1852-1908), with his characteristic gummed label on the front wrapper. $1250

**First Edition, Offprint Issue.** In 1905 Laue, who would win the 1914 Nobel Prize for his discovery of X-ray diffraction in crystals, was hired as Max Planck's assistant at the Institute for Theoretical Physics, where he remained for the next four years. "Two main results of this period are outstanding. The first concerns the application of the entropy concept to radiation fields, and the thermodynamical significance of the coherence of light waves. A strict definition of the degrees of freedom connected with radiation resulted from these considerations" (Ewald, p. 136). The present paper, on thermodynamic considerations of interference phenomena, relates to this facet of Laue's research during this period. This copy is from the library of French physicist Henri Becquerel, who shared the 1903 Nobel Prize with the Curies for their researches into radioactive phenomena. P. Ewald, "Max von Laue," *Royal Scoeity Biographical Memoirs* [1960]: 135-156). 50668

## *Archive of Laue Correspondence*

**167. Laue, Max von** (1879-1960). (1) Typed letter signed in German with typed and ms. corrections, dated 12.6.54 (June 12, 1954), to Rolf Hosemann (b. 1912), addressed to "Lieber Kollege" (dear colleague). 1-1/3pp., on single sheet with letterhead of the Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin. (2) Typed letter signed in German to Hosemann dated 19.7.54 (July 19, 1954). 1 page, on letterhead of the Institut as above. (3) Undated Typed letter signed (draft) in German, written in 1954 or later, to an unnamed member of the Stiftenverband für die Deutsche Wissenschaft. 2-1/4pp., on 2 sheets. (4) Printed circular letter in German dated 1.11.53 (November 1, 1953) with **von Laue's autograph signature** at the foot and Hosemann's name and the date



FRITZ-HABER-INSTITUT DER MAX-PLANCK-GESELLSCHAFT
- Der Direktor -

BERLIN-DAHLEM, DEN 19.7.54
FARADAYWEG 4 – 6
FERNRUF: 76 28 05/06

Herrn
Prof.Dr. H o s e m a n n
z.Zt. P a r i s

Lieber Kollege!

Ich habe gestern damit begonnen, Ihr Manuskript, den Bumerang, zu lesen und muss Ihnen gestehen, dass dieses Manuskript einen unendlich besseren Eindruck macht, als die früheren. Zwar bin ich nur bis Seite 7 (einschliesslich) gekommen und habe auch die ersten Anhänge gelesen und dabei noch eine Reihe von Randbemerkungen gemacht, die aber alle nur Formales betreffen. Ich werde mit der Lektüre fortfahren und hoffe, dass wir uns bei unserem nächsten Zusammentreffen sehr schnell einigen. Aber ich möchte, dass der wichtige Inhalt, der in dieser Arbeit steckt, auch eine ihm adäquate Form findet.

Um Ihnen einige meiner Bedenken sogleich mitzuteilen:

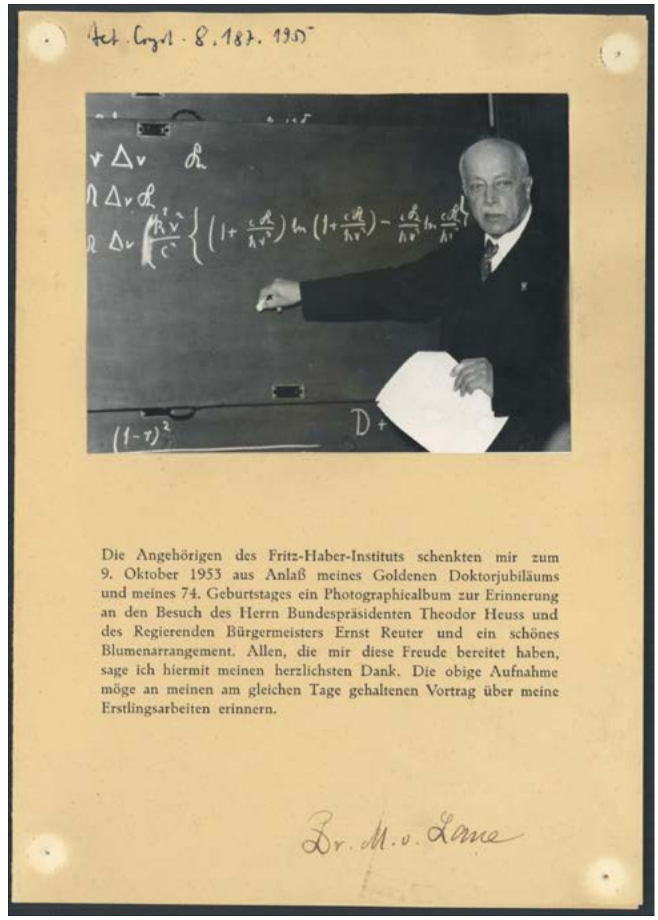
Als mehr an einer Stelle berufen Sie sich im Beweisgang auf spätere Gleichungen. Ich habe mich in allen diesen Fällen davon überzeugen können, dass dies überflüssig ist und darum unschädlich ist. Aber zunächst befürchtet der Leser doch, wenn er etwas Derartiges sieht, dass ein Zirkelschluss vorliegen müsste, insofern, als Sie ja die späteren Gleichungen aus den früheren ableiten.

Nochmals möchte ich bitten, den Kongressteilnehmern gegenüber zu betonen, wie gern ich gekommen wäre, wenn ich geglaubt hätte, dass ich dieses meiner Gesundheit zumuten könnte.

Mit herzlichem Gruss
Ihr

M. v. Laue

(Prof.Dr.M.von Laue)

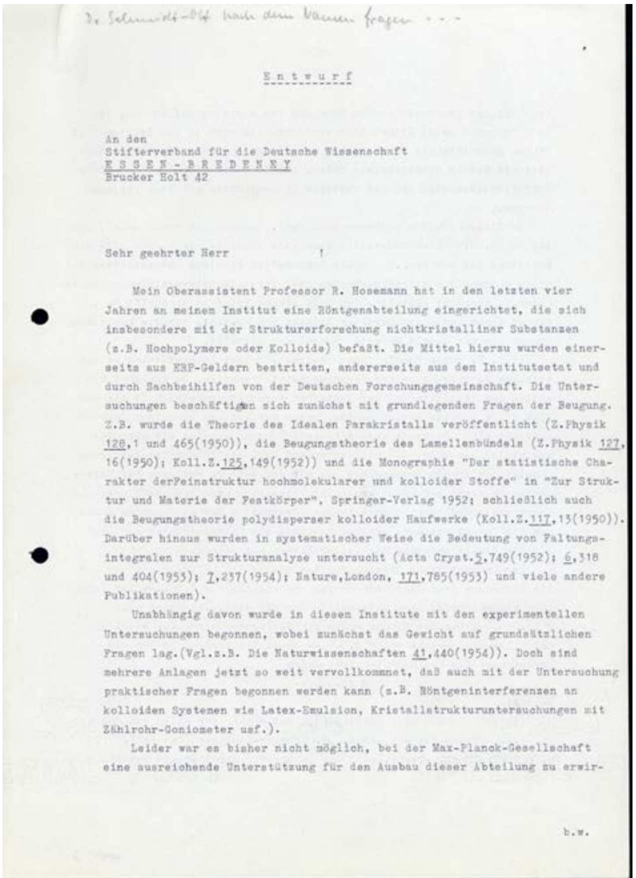


Die Angehörigen des Fritz-Haber-Instituts schenkten mir zum 9. Oktober 1953 aus Anlaß meines Goldenen Doktorjubiläums und meines 74. Geburtstages ein Photographiealbum zur Erinnerung an den Besuch des Herrn Bundespräsidenten Theodor Heuss und des Regierenden Bürgermeisters Ernst Reuter und ein schönes Blumenarrangement. Allen, die mir diese Freude bereitet haben, sage ich hiermit meinen herzlichsten Dank. Die obige Aufnahme möge an meinen am gleichen Tage gehaltenen Vortrag über meine Erstlingsarbeiten erinnern.

Dr. M. v. Laue

"3.5.1952" filled in by typewriter. 1 sheet, on letterhead of the Institut as above. (5) Printed thank-you note in German dated 9 October 1953, **signed in ink by von Laue**, with a **portrait photograph** of von Laue (85 x 114 mm.) attached. 4pp. 211 x 149 mm. Together 5 items, comprising the thank-you note and 4 letters on 5 sheets total, all measuring 292 x 211 mm.; all sheets punched for a two-hole binder. Letters creased where previously folded, slight soiling and wear, thank-you note a little dust-soiled and browned with thumbtack holes in each corner, but very good. English translations included. $7500

Max von Laue received the Nobel Prize for physics in 1914 for his discovery of the diffraction of x-rays in crystals, a discovery that Einstein called one of the most beautiful in physics. "Subsequently it was possible to investigate X radiation itself by means of wavelength determination as well as to study the structure of the irradiated material . . . The new field of X-ray structural analysis that Laue established developed into an important branch of physics and chemistry" (DSB). Laue continued to develop his theory of X-ray interference in the following decades, and did some important work on superconductivity as well. An early supporter of Einstein's theory of relativity, Laue was one of the few members of the Prussian Academy of Sciences to protest Einstein's dismissal from that organization in 1933 following the Nazi rise to power; that same year, Laue also successfully prevented the Academy from admitting Johannes Stark, the pro-Hitler physicist who believed relativity to be a "world-wide Jewish trick." After World War II Laue played an active role in rebuilding German science, founding the German Physical Society and re-establishing both the German Research Association and the Physikalisch-Technische Bundesanstalt. In April 1951, at the age of 71, Laue took over the directorship of the Fritz-Haber-Institut der Max-Planck-Gesellschaft, a post he occupied until his death nine years later.



Entwurf

An den
Stifterverband für die Deutsche Wissenschaft
ESSEN-BREDENEY
Brucker Holt 42

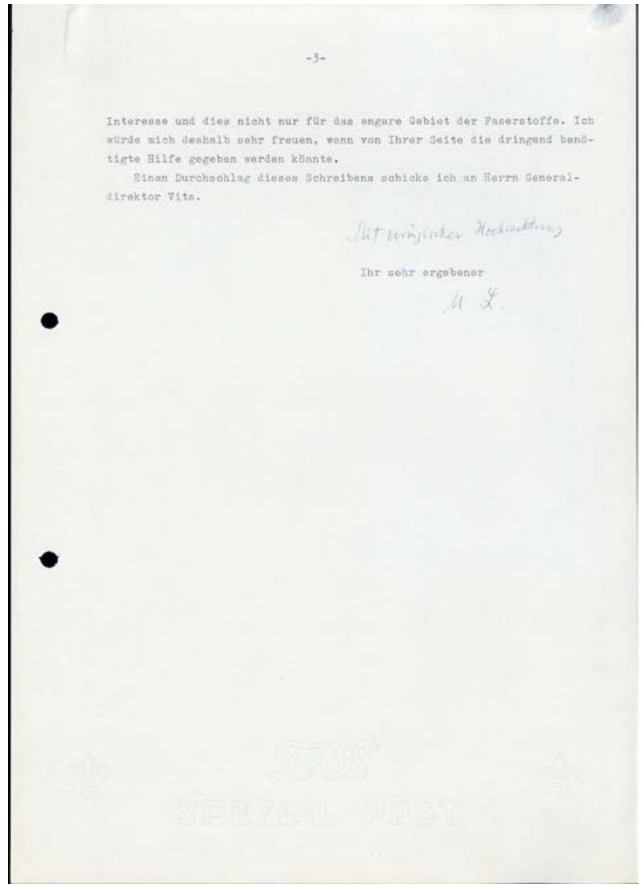
Sehr geehrter Herr !

Mein Oberassistent Professor R. Hosemann hat in den letzten vier Jahren an meinem Institut eine Röntgenabteilung eingerichtet, die sich insbesondere mit der Strukturerforschung nichtkristalliner Substanzen (z.B. Hochpolymere oder Kolloide) befaßt. Die Mittel hierzu wurden einerseits aus ERP-Geldern bestritten, andererseits aus dem Institutsetat und durch Sachbeihilfen von der Deutschen Forschungsgemeinschaft. Die Untersuchungen beschäftigten sich zunächst mit grundlegenden Fragen der Beugung. Z.B. wurde die Theorie des Idealen Parakristalls veröffentlicht (Z.Physik 128,1 und 465(1950)), die Beugungstheorie des Lamellenbündels (Z.Physik 127, 16(1950); Koll.Z.125,149(1952)) und die Monographie "Der statistische Charakter derFeinstruktur hochmolekularer und kolloider Stoffe" in "Zur Struktur und Materie der Festkörper", Springer-Verlag 1952; schließlich auch die Beugungstheorie polydisperser kolloider Haufwerke (Koll.Z.117,13(1950)). Darüber hinaus wurden in systematischer Weise die Bedeutung von Faltungsintegralen zur Strukturanalyse untersucht (Acta Cryst.5,749(1952); 6,318 und 404(1953); 7,237(1954); Nature,London, 171,785(1953) und viele andere Publikationen).

Unabhängig davon wurde in diesem Institute mit den experimentellen Untersuchungen begonnen, wobei zunächst das Gewicht auf grundsätzlichen Fragen lag.(Vgl.z.B. Die Naturwissenschaften 41,440(1954)). Doch sind mehrere Anlagen jetzt so weit vervollkommnet, daß auch mit der Untersuchung praktischer Fragen begonnen werden kann (z.B. Röntgeninterferenzen an kolloiden Systemen wie Latex-Emulsion, Kristallstrukturuntersuchungen mit Zählrohr-Goniometer usf.).

Leider war es bisher nicht möglich, bei der Max-Planck-Gesellschaft eine ausreichende Unterstützung für den Ausbau dieser Abteilung zu erwir-

b.w.



-3-

Interesse und dies nicht nur für das engere Gebiet der Faserstoffe. Ich würde mich deshalb sehr freuen, wenn von Ihrer Seite die dringend benötigte Hilfe gegeben werden könnte.

Einen Durchschlag dieses Schreibens schicke ich an Herrn Generaldirektor Vits.

Ihr sehr ergebener

This collection of materials contains two letters from Laue to Rolf Hosemann, his chief assistant at the Fritz-Haber-Institut. Hosemann had submitted a paper to Laue for review, and in (1), the first of his letters to Hosemann, von Laue critiques it thoroughly:

> I have gone to a lot of trouble with the second section of your work, "Lorentz-invariant deduction of Hamiltonian mechanics, Maxwellian electrodynamics and Schrödinger wave mechanics from the so-called general wave equation. Clarification of the wave-particle dualism." I have objections in many places . . .
>
> What do you want to do in this second section? The fact that you present the reader the mechanics of the mass point, which are well known to him, in a peculiar and most unpleasant notation, in my opinion, is rather superfluous. You want to begin with Equations (36) and (28), which are known to lead to the Hamiltonian equations of mechanics. What is the rest for? . . .
>
> You refer to de Broglie's agreement. Are you sure that he has actually studied your manuscript? Being French, he has a strong tendency to avoid an uncomfortable discussion by using some pleasing phrases.
>
> In any case, I cannot accept your manuscript as submitted for the Zeitschrift für Physik. In my opinion, the rewriting must rephrase the title, which promised entirely too much, to something more modest . . .
>
> I have now also read Section III. In this section you state that Section II has already covered the movement of a mass point in a specified electromagnetic field. The reader would be happy to believe that, because of the introduction of your "potential four-vector" $p_e$ was directed to that from the beginning. But these laws of motion do not by any means include all of electrodynamics . . . The claim you make at the beginning of the work, that you can derive electrodynamics from the relativity principle, completely misses the target.

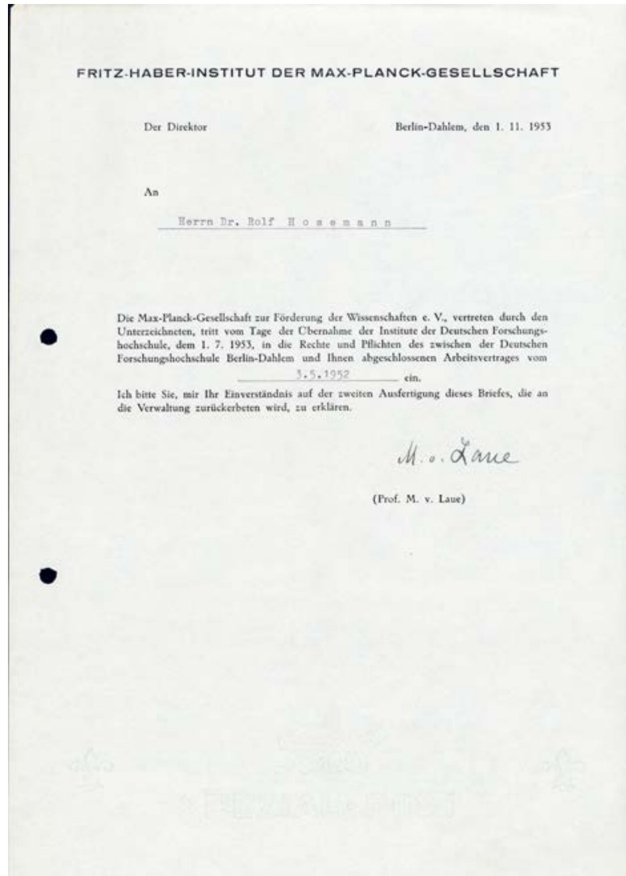
Hosemann then apparently sent Laue a rewrite of his paper, to which Laue responded in (2):

> I began yesterday to read your manuscript, the boomerang, and must admit that this manuscript makes an infinitely better impression than the previous one . . . I have made many marginal comments, but they only concern

format. I will continue reading, and hope that we will very quickly agree when we next meet. But I hope that the important content of your work will find a form adequate for it.

In order to inform you at once of some of my reservations:

At more than one point in your proof you refer to equations which appear later. I have convinced myself that this is superfluous in all of these cases, and therefore not harmful. But the reader, seeing something like that, immediately expects circular reasoning, as you derive the later equations from the earlier ones . . .


FRITZ-HABER-INSTITUT DER MAX-PLANCK-GESELLSCHAFT

Der Direktor

Berlin-Dahlem, den 1. 11. 1953

An

Herrn Dr. Rolf Hosemann

Die Max-Planck-Gesellschaft zur Förderung der Wissenschaften e. V., vertreten durch den Unterzeichneten, tritt vom Tage der Übernahme der Institute der Deutschen Forschungshochschule, dem 1. 7. 1953, in die Rechte und Pflichten des zwischen der Deutschen Forschungshochschule Berlin-Dahlem und Ihnen abgeschlossenen Arbeitsvertrages vom 3.5.1952 ein.

Ich bitte Sie, mir Ihr Einverständnis auf der zweiten Ausfertigung dieses Briefes, die an die Verwaltung zurückerbeten wird, zu erklären.

M. v. Laue

(Prof. M. v. Laue)

No. (3), the draft of a letter from Laue to the Stiftenverband für die Deutsche Wissenschaft (Society for the Support of German Science), contains a great deal of information about Hosemann and his work at the Fritz-Haber-Institut, as well as the type of research the Institut was engaged in, and some insight into how the Institut obtained its funding during the 1950s:

Over the last four years, my chief assistant, Professor R. Hosemann, established an X-ray department at my Institute concerned particularly with study of the structures of non-crystalline substances (e.g., high polymers or colloids) . . . The Institute first worked with fundamental problems of diffraction. For example, the theory of the ideal paracrystal was published (*Z. Physik* 128, 1 & 465 [1950]), as well as the diffraction theory of the lamellar bundle (*Z. Physik* 127, 16 [1950]; *Koll. Z.* 117, 13 [1950]). The monograph, "The statistical character of the fine structure of high-molecular weight and colloidal substances," was published in "On the Structure and Matter of Solids," Springer-Verlag, 1952 . . .

Independent of that, experimental studies initially concerned primarily with fundamental problems were started at this Institute (see, for example, *Die Naturwissenschaften* 41, 440 [1954]). But many of these works are so well completed that it is possible to start studying practical problems (e.g., X-ray interferences in colloidal systems such as latex emulsions, crystal structure studies with the counting tube goniometer, etc.)

Unfortunately, we have not yet been able to realize adequate support for the completion of this work at the Max Planck Society. Given the existing controls, then, we fear that Prof. Hosemann will lose his coworkers, who have worked very intensively and successfully for the last four years in this new and rather difficult field of work . . .

No. (4) is a printed circular letter addressed to Hosemann, concerning an agreement between the Institut and the Deutschen Forschungshochschule Berlin-Dahlem; no. (5) is a printed thank-you notice with original photograph, apparently sent to all who participated in the October 9, 1953 celebration of Laue's 74th birthday and the 50th anniversary of his receiving the doctorate.

Despite all his researches mentioned in no. (3) above, Laue's correspondent and assistant Hosemann is not mentioned in our reference works on the history of 20th century physics. OCLC and RLIN cite three monographs written or co-written by Hosemann: *Die Erforschung der Struktur hochmolekular und kolloider Stoffe mittels Kleiwinkelstreuung* (1952), mentioned in Laue's letter; *Lichtoptische Herstellung und Diskussion der Faltungsquadrate parakristaller Gitter* (1956); and *Direct Analysis of Diffraction by Matter* (1962). DSB. Weber, *Pioneers of Science,* pp. 49-50.
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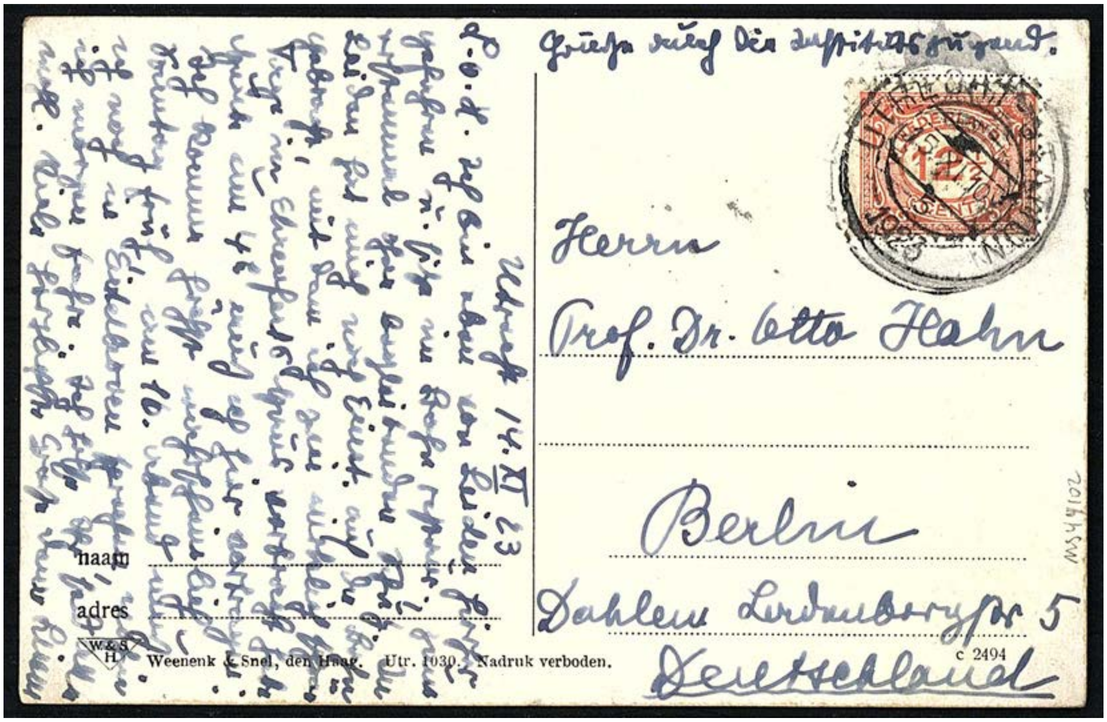



*". . . Einstein, with whom I spent two wonderful days in Ehrenfest's house . . ."*

**168. Meitner, Lise** (1878-1968). Autograph picture postcard signed, in German, to Otto Hahn (1879-1968). Utrecht, 14 September 1923 (postmarked the next day). 89 x 138 mm. One corner a bit bent, but very good. $5850

A fascinating postcard documenting not only the decades-long friendship and research collaboration between Meitner and Hahn, co-discoverers of nuclear fission, but also Meitner's friendship with Einstein and the important Dutch physicist Paul Ehrenfest with whom she had been friends since her student days. The postcard reads as follows:

> L[ieber] O[tto] H[ahn], Ich bin eben von Leiden hierher gefahren u[nd] sitze im Bahn […], zum erstenmal ohne begleitenden Schutz. In Leiden hat mich noch Einst[ein] auf die Bahn gebracht, mit dem ich zwei wirklich schöne Tage in Ehrenfests Haus verbracht habe. Heute um 4h muss ich hier abfahren. Ich komme höchst wahrscheinlich Sonntag früh, am 16. abend muß ich noch in Eindhoven […], wohin ich morgen fahre. Ich hoffe Ihr seid alle wohl. Viele herzliche Grüße, Deine Lise M. Grüße auch die Institutsjugend.
>
> I have just traveled here from Leiden and am sitting in the railway station, for the first time without accompanying protection. In Leiden Einstein, with whom I spent two wonderful days in Ehrenfest's house, escorted me to the train. I must leave from here at 4 o'clock. I will most probably return on Sunday morning; on the evening of the 16th I must [. . .] in Einthoven, where I am going tomorrow. I hope you are all well. Many hearty greetings, your Lise M. Greetings also to the Institute youth.

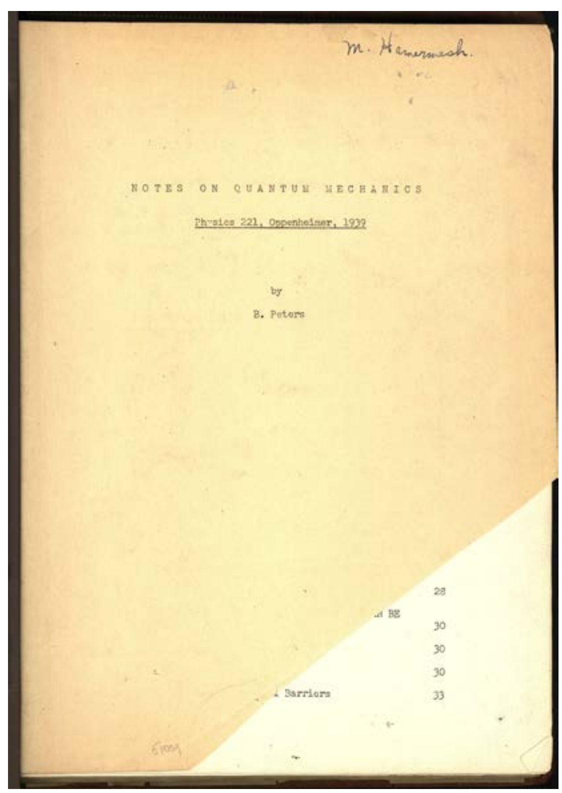
Meinter wrote the postcard during her first visit to the Netherlands, a lecture tour arranged by her friend Dirk Coster, professor of physics at the University of Groningen. Coster would later play a critical role in Meitner's life: In 1938 he persuaded her to leave Nazi Germany to avoid persecution as a Jew, and accompanied her during her the first leg of her escape, from Germany to the Netherlands.

Meitner obtained her doctorate in physics from the University of Vienna in 1905, where she became friends with her fellow student Paul Ehrenfest. In 1907 Max Planck invited her to Berlin to continue her post-doctoral studies; there she met radio-chemist Otto Hahn, who would be her research partner for the next thirty years, and also made the acquaintance of Einstein. During those early years in Berlin, before the outbreak of World War I, Einstein, Ehrenfest, Meitner and others would often gather at Planck's home for long evenings of music and conversation.

In 1912 Hahn and Meitner joined the Kaiser Wilhelm Institute for Chemistry in Berlin (Meitner as an unpaid "guest" due to the fact that she was a woman), where they investigated the complex physical properties of radioactive elements and discovered the element protactinium (Pa). In 1919 Meitner was made a professor at the KWI, where she served as head of the Institute's physics department, and in 1926 she was appointed full professor of physics at the University of Berlin—the first woman in Germany to hold such a post. Between 1924 and 1934 the Hahn-Meitner team gained international prestige with their work in what became known as nuclear physics. In 1934, after learning about the results of Fermi's neutron bombardment of uranium, Meitner persuaded Hahn and his assistant, Fritz Strassmann, to join her in a thorough investigation of these phenomena. During the next four years (1934-38) the Meitner-Hahn-Strassmann team identified numerous radioactive "transuranes" resulting from neutron bombardment of uranium; although the chemical evidence for these elements appeared strong, the physics of their creation—which conformed to no known pattern—puzzled Meitner deeply. Meitner also had other problems to contend with—as a Jew in Nazi Germany, she found her career and even her life becoming steadily more endangered, and in July 1938, with the aid of Dirk Coster, she fled to safety in Stockholm. Although forced to abandon her hands-on investigations at the KWI, Meitner maintained a constant scientific correspondence with Hahn, and was thus kept abreast of their ongoing researches.

In 1938 Hahn and Strassmann, continuing with the irradiated uranium investigations, discovered barium isotopes among the decay products produced by the bombarded nuclei. At a loss to interpret this result, the two men communicated their result by letter to Meitner, who, with the help of her nephew Otto Frisch (a member of Bohr's Copenhagen Institute for Theoretical Physics), came up with the correct explanation: The large uranium nucleus breaks up upon bombardment into two or more smaller nuclei through the mutual repulsion of its many protons, which makes it behave like a droplet of water in which the surface tension has been reduced. By taking the difference between the mass of the original nucleus and the slightly smaller total mass of the fragment nuclei, and using Einstein's mass-energy equivalence, Meitner calculated the large amount of energy (equal to 200 million electron volts) that would be released during the splitting process, which she and Frisch named "fission." Sime, *Lise Meitner,* p. 99. 44102

## *One of Oppenheimer's Rarest Publications*




**169.** [**Oppenheimer, J. Robert** (1904-67)]. **Peters, Bernard** (b. 1910). Notes on quantum mechanics. Physics 221, Oppenheimer, 1939. Mimeograph typescript. [4], 138ff., printed on rectos only. [Berkeley, 1939]. 277 x 215 mm. Original wire-stitched wrappers, title mimeographed on front wrapper, lower corner of front wrapper cut away, minor soiling and wear; in cardboard binder with handwritten paper label on the front cover. Very good copy. From the library of American physicist Morton Hamermesh (1915-2003), with his signature on the front wrapper; 2 pages of pencil notes on yellow lined paper, possibly by Hamermesh, laid in. $5000

**First Edition. One of the earliest English-language textbooks of quantum physics.** Oppenheimer, who had distinguished himself brilliantly in quantum physics during the previous decade, began teaching at Berkeley and Caltech in 1929, where he founded "the greatest school of theoretical physics that the United States has ever known"

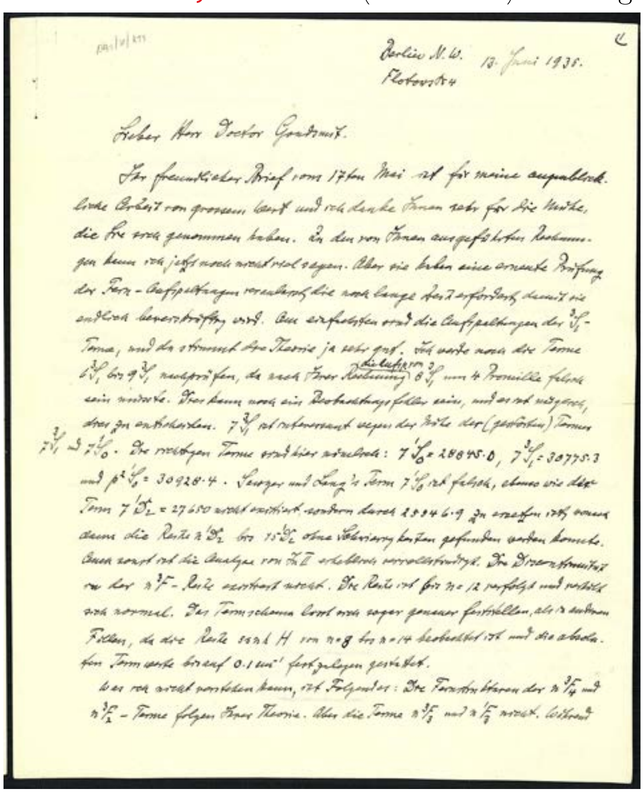
(Bethe, p. 396). At the time this course was given and these notes prepared, no substantive English-language work was available to students to learn quantum theory, and so it fell to Oppenheimer to create a text-book of sorts for the use of his students, resulting in this mimeographed publication. "[Oppenheimer's] course was an inspirational, as well as educational achievement. He transmitted to his students a feeling of the beauty of the logical structure of physics and an excitement in the development of science. Almost everyone listened to the course more than once, and Oppie occasionally had difficulty in dissuading students from coming a third or fourth time . . . Its graduates, Leonard Schiff in particular, carried it, each in his own version, to many campuses" (Rabi et al., *Oppenheimer,* p. 18).

The syllabus was prepared by Oppenheimer's student Bernard Peters; it was reprinted in 1948 by the University of California Press. The mimeographed version is *scarce,* with OCLC recording only seven North American libraries with copies (University of California, Cal Tech, Linda Hall Lib., American Institute of Physics, Oklahoma University, Princeton & Martin Marietta [Oak Ridge, TN]). **It is probably the rarest of Oppenheimer's publications.**

This copy was once owned by Morton Hamermesh, who possibly obtained it while doing postdoctoral research at Stanford University. Hamermesh would later collaborate with Nobel laureate Julian Schwinger on the scattering of slow neutrons, and author the highly regarded textbook *Group Theory and its Application to Physical Problems* (1962). Bethe, "J. Robert Oppenheimer 1904-1967, *Royal Society Biographical Memoirs* (1968): 391-416. 51009

## *His Scientific Archives Destroyed in Bombing Raid*
## *Only 189 Letters Survive, of which Five Offered Here are Previously Unknown*

**170. Paschen, Friedrich** (1865-1947). 6 Autograph letters signed. to Samuel Goudsmit (1902-78). Charlottenburg or Berlin, January 15, 1932-June 13, 1935. 13pp. total on 7 sheets measuring either 237 x 208 mm. or 286 x 223 mm. Creased where previously folded, with minor soiling and wear along creases, otherwise fine. English translations included. $3500


Berlin N.W.
Flotowstr. 4
13. Juni 1935.

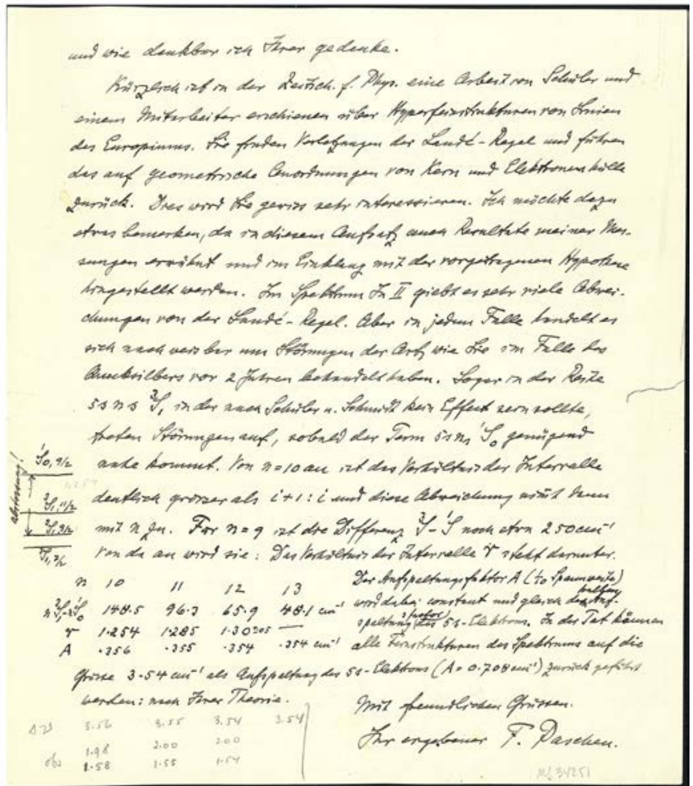
Lieber Herr Doctor Goudsmit.

Ihr freundlicher Brief vom 17ten Mai ist für meine augenblickliche Arbeit von grossem Wert und ich danke Ihnen sehr für die Mühe, die Sie sich genommen haben. [illegible]

Excellent series of very technical scientific letters to Goudsmit discussing his ongoing investigations in spectroscopy, particularly problems of hyperfine structure and the Zeeman effect. Described by one biographer as "probably the greatest experimental spectroscopist of his time" (quoted in DSB), Paschen, in the words of Niels Bohr, had a "happy intuition" that led him always to "pursue experimentally those problems the investigation of which proved to be of decisive significance for the extension of general theoretical conceptions" (quoted in DSB). Paschen's experimental work in spectroscopy provided some of the most revealing clues to atomic structure; it was particularly useful to Arnold Sommerfeld, whose modifications of Bohr's theory of atomic structure had impressed Paschen so much that he devoted six months to confirming the theory's predictions. During his tenure as professor of physics at the University of Tübingen (1901-24), Paschen made Tübingen into Germany's most important center of atomic spectroscopy. In 1924 he succeeded

Nernst as president of the Physikalische-Technische Reichsanstalt, the highest post to which a German experimental physicist could aspire; on May 1, 1933, after the Nazi's seizure of power in Germany, he was forced to retire in favor of the pro-Nazi physicist Johannes Stark. Despite this setback, Paschen was able to continue his laboratory research for a few years afterward—although at the cost of considerable difficulty and personal humiliation, some of which is hinted at in the letters offered here.

These six letters from Paschen to Goudsmit are almost exclusively concerned with the scientific investigations performed by the two men during the years 1932-1935; they exemplify the interplay between theoretical and experimental physics so characteristic of Paschen's career. This is particularly apparent in the last four letters (August 22, 1933-June 13, 1935), in which Paschen provided Goudsmit with detailed information on the results of his latest researches:



und wie dankbar ich Ihrer gedenke.

Kürzlich ist in der Zeitsch. f. Phys. eine Arbeit von Schüler und einem Mitarbeiter erschienen über Hyperfeinstrukturen von Linien des Europiums. Sie finden Verletzungen der Landé-Regel und führen das auf geometrische Anordnungen von Kern und Elektronenhülle zurück. Dies wird Sie gewiss sehr interessieren. Ich möchte dazu etwas bemerken, da in diesem Aufsatz auch Resultate meiner Messungen erwähnt und im Einklang mit der vorgetragenen Hypothese hingestellt werden. Im Spektrum In II giebt es sehr viele Abweichungen von der Landé-Regel. Aber in jedem Falle handelt es sich nachweisbar um Störungen der Art wie Sie im Falle des Quecksilbers vor 2 Jahren behandelt haben. Sogar in der Reihe $5s\,ns\ {}^3S_1$, in der nach Schüler u. Schmidt kein Effekt sein sollte, treten Störungen auf, sobald der Term $5s\,n_1\ {}^1S_0$ genügend nahe kommt. Von n=10 an ist das Verhältnis der Intervalle deutlich grösser als i+1 : i und diese Abweichung wächst dann mit n an. Für n=9 ist die Differenz ${}^3S-{}^1S$ noch etwa 250 cm⁻¹ von da an wird sie: Das Verhältnis der Intervalle γ steht darunter.

| n | 10 | 11 | 12 | 13 |
|---|---|---|---|---|
| $n\,{}^3S_1-{}^1S_0$ | 148.5 | 96.3 | 65.9 | 48.1 cm⁻¹ |
| γ | 1.254 | 1.285 | 1.302 | — |
| A | .356 | .355 | .354 | .354 cm⁻¹ |

Der Aufspaltungsfaktor A (…) wird daher constant und gleich der Aufspaltung des 5s-Elektrons. In der That können alle Feinstrukturen des Spektrums auf die Grösse 3.54 cm⁻¹ als Aufspaltung des 5s-Elektrons (A = 0.708 cm⁻¹) zurückgeführt werden: nach Ihrer Theorie.

Mit freundlichen Grüssen.

Ihr ergebener F. Paschen.

Thank you so much for kindly sending me your and Mr. Bacher's work on anomalies in hyperfine structures. At the same time please accept my cordial congratulations on your wonderful <u>quantitative</u> settlement of the disputed questions regarding Al II and Hg I. For Al everything now appears to be in perfect order. Also, in the meantime I have become convinced that two fine structure components of the two lines $4\ {}^{1,3}F_3$-nG are simple and do not have any weak companions. Accordingly, the term nG must be split with 0.48 $cm^{-1}$, as you conclude, and not with 0.35 as I assumed . . . It is fascinating how the same problem is approached independently from several angles. However, your work is very important because you derive quantitative, definitive results.

And in his letter of Aug. 22, 1933:

You were so kind to write me concerning the theoretical fundamentals for comprehending the fine structures of the lines of Al II. Since you went to such trouble, I assume that the progress of my work on this topic would be of interest to you and would like to inform you that the publication thereof will not be forthcoming for some time . . . I have made a study of extensive new material and have progressed to the point that the entire spectrum can be based quite soundly on the values of the fine structure terms . . . All triplet terms now have two different numerical values corresponding to j + 1/2 and j - 1/2, which are based on the fine structure splitting values that you provided . . .

Paschen's letter of April 28, 1935 praised Goudsmit and Pauling's *The Structure of Line Spectra* (1930) and discussed Schüler's article on the hyperfine structures of europium:

The book by Pauling and Goudsmit is today the "bible" of the practical spectroscopist. However, your experimental studies, the fundamentals of hyperfine structures, conducted in collaboration with Back, belong to the classic works of spectroscopy . . . An article by Schüler and a colleague on hyperfine structures of lines of europium recently appeared in *Zeitschrift für Physik*. The authors find violations of the Laudé rule and attribute this to the geometric arrangement of nucleus and electron shell. This will certainly be of interest to you. I would like to point out that in this article results of my measurements are also mentioned and are presented in support of the proposed hypothesis. The spectrum In II contains a great many deviations from the Laudé rule. However, in any event they involve detectable disturbances of the type that you discussed in the case of mercury two years ago.

And in the final letter of June 13, 1935:

> Your kind letter of May 17 is of great value to my current research and I am very grateful for the effort you put into it. At this time I cannot say very much about the calculations you provided, but you have inspired a renewed testing of fine splittings that will require much time before it is ultimately conclusive. [A detailed numerical analysis of the fine splittings of various terms follows.] . . . I am conveying these details to you since you appear to hold the key for the peculiar splittings of the $^{1,3}F_3$ terms. I myself am so deeply involved with the measurements and thereby so overloaded with numbers that I cannot yet delve into the theory. However, clarifying the F terms interests me and does not seem to be difficult for you . . . Similar to the Runge rule for the anomalous Zeeman effects, only whole-number fragments of the splitting factor A = a or the span S = EMBED Equation.2 will thus always be present. In this regard the fine structure is indicated as Zeeman effect of the nuclear moment.
>
> This is my interpretation as an experimental physicist, even if it is theoretically self-evident. The conclusion I was inclined to draw, that namely absolutely no fine structure splittings can occur other than such whole-number fragments, is however much more difficult to substantiate than with the Zeeman splittings, since the splittings are too small and the measurements lack the required accuracy.

The first two letters in this series, although briefer, are also of interest. In the first (January 15, 1932), Paschen gave Goudsmit permission to include the Rydberg spectrographic tables in a proposed study, and praised Goudsmit for "the wonderful and renowned articles you have published to advance theoretical and practical spectroscopy. The discovery of electron spin was a very great accomplishment . . ." In the second (April 9, 1933), Paschen acknowledged Goudsmit's gift of a copy of his and Bacher's *Atomic Energy States* (1932): "I would like to express my highest gratitude for this valuable dedication and at the same time express my delight in seeing that you undertook this effort of producing this valuable but laborious work. All spectroscopists will be greatly indebted to you. So far I have read only the introduction and I have been delighted by the precise and clear presentation. I will now use the tables quite extensively, since they render the extremely tedious bibliographic search superfluous."

According to the *Dictionary of Scientific Biography*, all of Paschen's scientific manuscripts perished in November 1943 when his house was destroyed in a bombing raid; thus his letters to scientific colleagues such as Goudsmit represent his only surviving unpublished work in physics. The *Dictionary of Scientific Biography* gives an inventory of 184 known letters by Paschen to other physicists, taken from Kuhn's *Sources for the History of Quantum Physics* and the catalogues of the Niels Bohr Institute and the American Institute of Physics; of these 184 letters, *only one to Goudsmit* (the Jan. 15, 1932 letter included in the present collection) is cited. The collection of letters we are offering here, replete with formulae and scientific data, thus marks an important and valuable addition to the Paschen canon. 34255

**171. Pauli, Wolfgang** (1900-1958). Die Ausbreitung des Lichtes in bewegten Medien. Offprint from *Mathematische Annalen* 82 (1920). 113-119pp. 229 x 156 mm. Original printed wrappers, toned, a few very minor creases, chips and marginal tears. Very good. $1500

**First Edition, Offprint Issue** of Pauli's fourth published paper, written while he was a student under Arnold Sommerfeld at the University of Munich. Pauli wrote this paper at the suggestion of Sommerfeld, whom Pauli referred to deferentially in his introduction as "my highly revered teacher" (p. 113). The paper, "a critique of some published false results on special relativity" (Enz, p. 55), was a response to Karl Uller's "Eine Kritik der Elektrodynamik und Relativistik" (1919); Uller, a professor of physics at Giessen, had rejected Einstein's theory of relativity. Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli*, p. 55. 45928

**172.** [**Pauli, Wolfgang** (1900-1958).] **Born, Max** (1882-1970) and **Pauli.** Über die Quantelung gestörter mechanischer Systeme. Offprint from *Zeitschrift für Physik* 10 (1922). 137-158pp. 230 x 154 mm. Original printed wrappers, slightly soiled and creased. Very good. From the library of H. A. Kramers (1894-1952), with his pencil signature on the front wrapper. $1750

**First Edition, Offprint Issue.** During his sojourn at the University of Göttingen during the winter 1921-22 semester, Pauli collaborated with Born on the formulation of a general perturbation theory, using an approximation method developed by Born and E. Brody; "this approximation method, well known from the astronomical calculations of planetary orbits, had been introduced into atomic physics by Bohr in 1918 and elaborated on by his assistant Kramers in 1920 and by Born and Brody in 1921" (Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* p. 79). Born and Pauli's task "consisted in developing a method which would allow one to find successive approximations for arbitrary mechanical systems, i.e., to establish a systematic quantum-theoretical perturbation scheme for the description of any atom or molecule. This scheme should then enable the physicists to compute, for example, the energy of atomic systems to a given accuracy" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 1, p. 409).

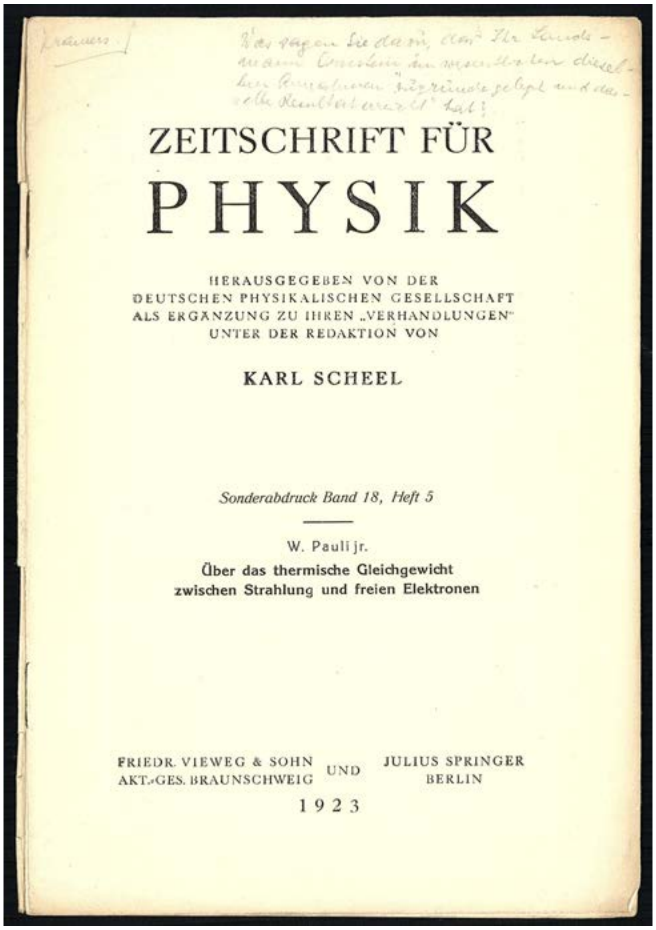
This copy is from the library of H. A. Kramers, one of the major architects of quantum theory, who, as noted above, had published a paper in 1920 on perturbation theory; Born and Pauli reference Kramers's paper on p. 137. 50960

**173. Pauli, Wolfgang** (1900-1958). Über das Modell des Wasserstoffmolekülions. Offprint from *Annalen der Physik*, 4th series, 68 (1922). 177-240pp. 227 x 145 mm. Without wrappers as issued, small chips at spine extremities. Minor toning but very good. Presented by Pauli to physicist Gregor Wentzel (1898-1978), with Pauli's pencil inscription "Wentzel" on the first leaf. $2750

**First Edition, Rare Offprint Issue** of Pauli's doctoral thesis. At the urging of his teacher, Arnold Sommerfeld, Pauli chose as his topic the quantum theory of ionized molecular hydrogen (H2+), which contains two protons and one electron. As Heisenberg (also a student of Sommerfeld's) later recalled, Pauli "wanted to examine if, in a complicated system for which one was just barely capable of doing the calculations, Bohr's theory and the Bohr-Sommerfeld quantum conditions led to the experimentally correct result. For, in our Munich discussions doubts had come to us whether the hitherto obtained successes of the theory were not limited to simple systems and whether a failure might not occur already in the more complicated system" (quoted in Enz, No Time to be Brief: A Scientific Biography of Wolfgang Pauli, p. 63). Pauli's efforts, although they obtained him his doctorate, did not yield a successful quantum theory of H2+; according to Born, who reviewed Pauli's work on H2+ in his Lectures on Quantum Mechanics, the resulting energy values "cannot be made to agree with the measurements of the ionization and excitation voltages" (quoted in Enz, p. 69). The problem of the hydrogen molecular ion was not solved until 1927, when Øyvind Burrau published the first successful quantum-mechanical treatment of H2+. 43387

## *Inscribed by Pauli to Kramers*

**174. Pauli, Wolfgang** (1900-1958). Über das thermische Gleichgewicht zwischen Strahlung und freien Elektronen. Offprint from *Zeitschrift für Physik* 18 (1923). 272-286pp. 229 x 158 mm. Original printed wrappers, a bit worn, small splits and tears in spine. Very good. *Presentation Copy, Inscribed by Pauli to H. A. Kramers* (1894-1952) on the front wrapper: "Kramers [in upper left corner] Was sagen Sie dazu, daß Ihr Landsmann Ornstein im wesentlichen dieselben Annahmen 'zugrunde gelegt und dasselbe Resultat erricht' hat?" $2500




**First Edition, Offprint Issue.** Written during his time at Bohr's laboratory in Copenhagen, Pauli's paper "gives and interesting and not well-known derivation of Planck's radiation law, based on the energy-momentum conservation for the Compton effect . . . Pauli then remarks that a generalization of this procedure to other systems, such as atoms, allows one to consider optical dispersion phenomena. As observed by Bohr, this generalization is very closely related to Kramers' dispersion relation" (Enz, pp. 781-782).

Pauli presented this copy of his paper to Kramers, one of the main architects, along with Heisenberg, Schrödinger and Pauli, of quantum mechanics. Pauli became friends with Kramers during his time in Copenhagen, where Kramers worked for many years as Bohr's assistant. Pauli's inscription can be translated as "What do you say about the fact that your compatriot Ornstein essentially 'made the same assumptions and achieved the same result'?" Pauli is quoting here from a paper by Dutch physicists Leonard S. Ornstein and H. C. Burger that had appeared in the *Zeitschrift für Physik*—either "Die Dimension der Einsteinschen Lichtquanten" (Vol. 20, pp. 345-350) or "Zur Dynamik des Stoßes zwischen einem Lichtquant und einem Elektron" (Vol. 20, pp. 351-357). Enz, "W. Pauli's scientific work," in J. Mehra, ed., *The Physicist's Conception of Nature,* pp. 766-799. 45903

**175. Pauli, Wolfgang** (1900-1958). Über die Gesetzmäßigkeiten des anomalen Zeemaneffektes. Offprint from *Zeitschrift für Physik* 16 (1923). 155-164pp. 229 x 155 mm. Original printed wrappers, vertically creased, light soiling and fraying. Very good. From the library of H. A. Kramers (1894-1952), with his pencil signature on the front wrapper. $2750

**First Edition, Offprint Issue** of Pauli's paper on the regularities of the anomalous Zeeman effect, in which he found a means of explaining this phenomenon without relying on Heisenberg's core model of the atom. "The differences between Heisenberg's method of doing physics and Pauli's came to a focus on the problem of the anomalous Zeeman effect. The core model had served as the basis for the earlier work Heisenberg had done on this problem . . . In 1923 Pauli, who was then working in Copenhagen, began an intensive study of the anomalous Zeeman effect, trying to generalize the Landé-Heisenberg results while dispensing with any reliance on models. Basically what he did was to treat the established results as empirical generalizations from observational data, rather than as conclusions dependent on any particular model . . . Pauli [showed] that it was possible to explain the anomalous Zeeman effect while dispensing with [Heisenberg's] core plus electron model" (Kragh, pp. 157-158). Two years later, in his first paper on the exclusion principle, Pauli would show that Heisenberg's core model was wrong.

This copy is from the library of Dutch physicist H. A. Kramers, one of the primary architects of quantum theory. Kragh, "The genesis of Dirac's relativistic theory of electrons," in *Science and Society: Quantum Histories,* ed. P. Galison, M. Gordin and D. Kaiser (New York: Routledge, 2001), pp. 153-189. 50963

**176. Pauli, Wolfgang** (1900-1958). Über die Gesetzmäßigkeiten des anomalen Zeemaneffektes. Offprint from *Zeitschrift für Physik* 16 (1923). 155-164pp. 229 x 155 mm. Original printed wrappers, 2 holes punched in the left margin, slight soiling. Very good. From the library of American theoretical physicist Frank C. Hoyt (1898-1980), with his signature on the front wrapper. $1250

**First Edition, Offprint Issue.** This copy is from the library of Frank C. Hoyt, one of the first American theoretical physicists to participate in the development of quantum physics. Hoyt became acquainted with Pauli in Copenhagen when both of them were researchers at Niels Bohr's Institute for Theoretical Physics. Kragh, "The genesis of Dirac's relativistic theory of electrons," in *Science and Society: Quantum Histories,* ed. P. Galison, M. Gordin and D. Kaiser (New York: Routledge, 2001), pp. 153-189. 50964

**177. Pauli, Wolfgang** (1900-1958). Zur Frage der Zuordnung der Komplexstrukturterme in starken und in schwachen äußeren Feldern. Offprint from *Zeitschrift für Physik* 20 (1924). 371-387pp. 227 x 158 mm. Original printed wrappers, a bit worn and soiled, small splits in spine. Very good. *Presentation Copy, Inscribed by Pauli to H. A. Kramers* on the front wrapper: "Seinem lieben Freund H. A. Kramers mit dem Motto: "Glucklich ist, wer vergisst, was doch nicht zuändern ist." $1750

**First Edition, Offprint Issue.** Pauli's second paper on the anomalous Zeeman effect, showing "that Landé's association of the quantum numbers in the cases of weak and strong fields . . . could be derived from the rules of the old quantum theory" (Enz, p. 770). The anomalous Zeeman effect, in which certain spectral lines in a magnetic field split into four rather than three, defied the predictions of classical physics. Pauli began investigating this puzzling phenomenon in 1922 while working in Bohr's laboratory in Copenhagen, continuing his researches after his return to Germany in the fall of 1923. His work on the Zeeman effect eventually resulted in the formulation of the famous Pauli exclusion principle (1924-25), for which he received the 1945 Nobel Prize in physics.

Pauli presented this copy of his paper to Dutch physicist H. A. Kramers (1894-1952), one of the main architects, along with Heisenberg, Schrödinger and Pauli, of quantum mechanics. Pauli became friends with Kramers during his time in Copenhagen, where Kramers worked for many years as Bohr's assistant. Pauli's inscription can be translated as "To his dear friend H. A. Kramers with the motto: 'Happy is he who forgets what cannot be changed.'" Enz, "W. Pauli's scientific work," in J. Mehra, ed., *The Physicist's Conception of Nature,* pp. 766-799. 45902

**178. Pauli, Wolfgang** (1900-1958). Zur Frage der theoretischen Deutung der Satelliten einiger Spektrallinien und ihrer Beeinflussung durch magnetische Felder. Offprint from *Die Naturwissenschaften* 12 (1924). 741-743pp. 271 x 195 mm. Bifolium; without wrappers as issued. Creased horizontally, small marginal tears, light soiling. Good to very good. From the library of H. A. Kramers (1894-1952), with his pencil signature on the first page. $1750

**First Edition, Offprint Issue.** Pauli was initially opposed to the idea of electron spin, calling it "ridiculous" when Goudsmit and Uhlenbeck proposed it in 1925; he accepted spin (reluctantly) only after Llewellyn Thomas and other physicists confirmed Goudsmit and Uhlenbeck's results. However, in his Nobel Prize lecture (1945), Pauli asserted his own priority in the discovery of spin on the basis of the present paper on hyperfine structures:

I may include the historical remark that already in 1924, before electron spin was discovered, I proposed to use the assumption of a nuclear spin to interpret the hyperfine structure of spectral lines. This proposal met on the one hand strong opposition from many sides but influenced on the other hand Goudsmit and Uhlenbeck in their claim of an electron spin (quoted in Enz, p. 118).

Pauli's claim naturally irritated Goudsmit and Uhlenbeck, who in fact had not seen Pauli's paper prior to publishing their own. Pauli's 1924 paper had in fact proposed the idea of a spinning *nucleus*, which led his biographer to later write that "Pauli could at the same time propose the idea of the nuclear spin and reject the apparently identical idea of the electron spin" (Enz, p. 119) because of the nucleus's smaller peripheral velocities.

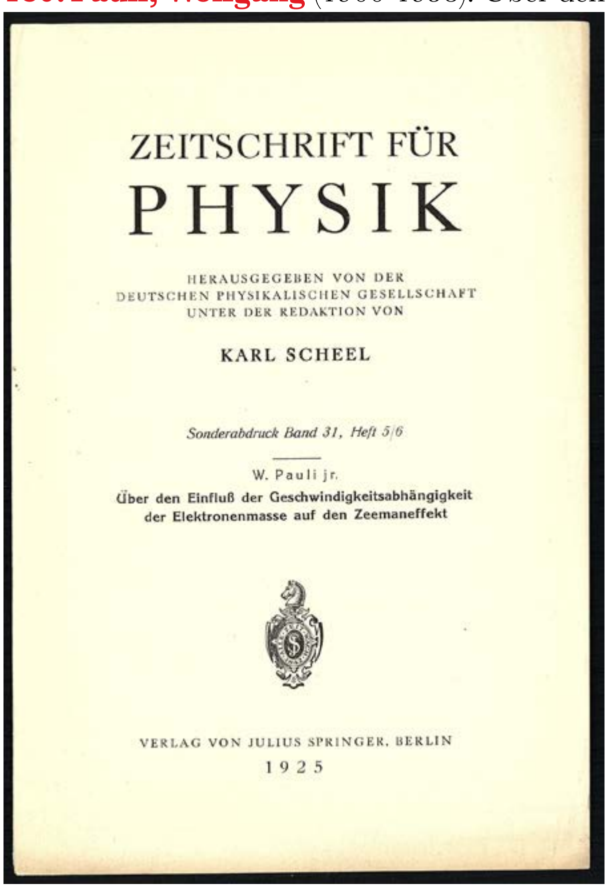
This copy is from the library of Dutch physicist H. A. Kramers, one of the primary architects of quantum theory. Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* pp. 116-119. 50928

**179. Pauli, Wolfgang** (1900-1958). Ueber die Intensitäten der im elektrischen Feld erscheinenden Kombinationslinien. Offprint from *Det Kgl. Danske Videskabernes Selskab., Math.-fys. Meddelelser* 7 (1925). 20pp. 240 x 150 mm. (unopened). Original printed wrappers, edges a bit frayed and chipped, small tears in front wrapper. Very good. $1000

**First Edition, Offprint Issue.** Pauli's paper on the intensities of the combination lines that occur during the Stark effect (the shifting and splitting of spectral lines in the presence of an external electric field) made use of some the ideas Pauli would apply a year later in his famous quantum-mechanical solution of the hydrogen atom (1926). Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* p. 81. 45929

## *Pauli's First Paper on his Exclusion Principle*

**180. Pauli, Wolfgang** (1900-1958). Über den Einfluss der Geschwindigkeitsabhängigkeit der Elektronenmasse auf den Zeemaneffekt. Offprint from *Zeitschrift für Physik* 31 (1925). 373-385pp. 230 x 157 mm. Original printed wrappers. Fine copy. $17,500




**First Edition, Extremely Rare Offprint Issue** of Pauli's first paper on the exclusion principle, "the crowning conclusion to the old quantum theory" (*Dictionary of Scientific Biography*), for which Pauli was awarded the Nobel Prize in 1945. This is only the third copy of the offprint of Pauli's paper that we have seen on the market in our over fifty years of experience.

Pauli's exclusion principle states that no two atoms in an electron can be in the same quantum state. The principle grew out of Pauli's investigations into the anomalous Zeeman effect, undertaken in 1922-1923 during his first visit to Copenhagen. The Zeeman effect (named after Pieter Zeeman, who won the Nobel Prize for discovering it) is the splitting of spectral lines in a strong magnetic field. Classical mechanics theory predicted that the spectral lines would split into three, but in 1898 it was observed that a certain line in the sodium spectrum actually splits into four lines—the first example of what is now called the anomalous Zeeman effect. After wrestling with the Zeeman problem in Copenhagen, Pauli returned to Germany where he began critically examining the attempts of Bohr and other physicists to explain the phenomenon.

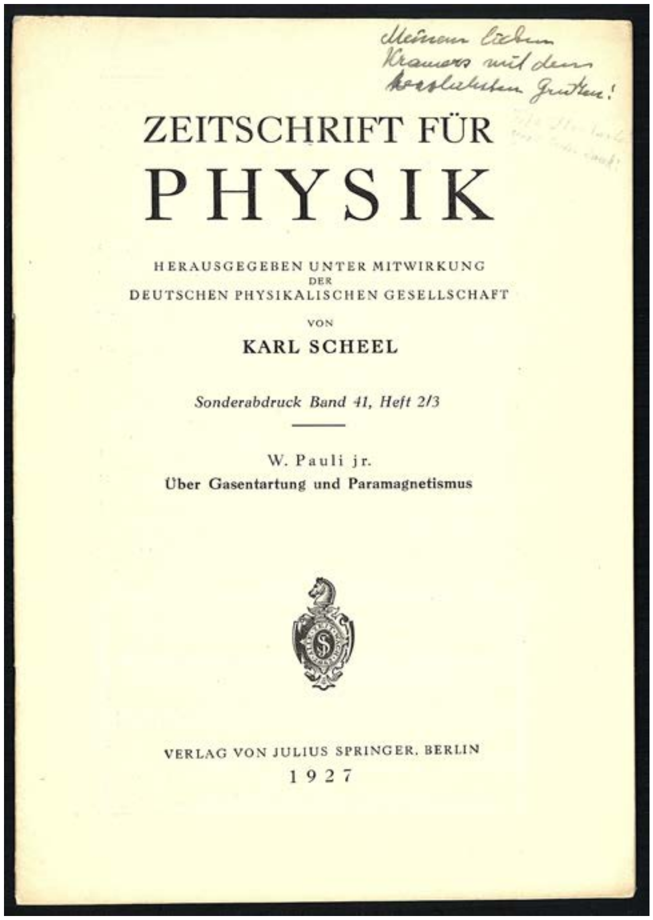
> According to the view then orthodox, which was also taken over by Bohr . . . a non-vanishing angular momentum of the atomic core was supposed to be the cause of this doublet structure. In the autumn of 1924 [the date the present paper was submitted], I published some arguments against this point of view, which I definitely rejected as incorrect and proposed instead of it the assumption of a new quantum theoretic property of the electron, which I called a "two-valuedness not describable classically" (Pauli, p. 29).

Pauli expanded his arguments in a second paper published six weeks later, which contained the general formulation of his exclusion principle. "Wolfgang Pauli - Nobel Lecture: Exclusion Principle and Quantum Mechanics". Nobelprize.org. Nobel Media AB 2014. Web. Accessed 18 Dec 2014. Ezhela et al., *Particle Physics: One Hundred Years of Discoveries*, p. 42. 45882

## *Beginning of "the Modern Electron Theory of Metals"—Presentation Copy*

**181. Pauli, Wolfgang** (1900-1958). Über Gasentartung und Paramagnetismus. Offprint from *Zeitschrift für Physik* 41 (1927). 81-102pp. 228 x 156 mm. Original printed wrappers, slightly worn. Very good. *Presentation Copy, Inscribed by Pauli to H. A. Kramers* (1894-1952) on the front wrapper: "Meinem lieben Kramers mit den herzlichsten Grüßen! [in pen] Für Ihre Karte noch besten Dank! [in pencil]." Laid in is an autograph letter signed in Dutch to Kramers, dated 11 March 1927, from Fr. W. Wolthoff[?] at the Pharmaceutisch Laboratorium der Rijks-Universiteit, Utrecht; the letter contains some pencil calculations in the left margin possibly by Kramers.

$8500




**First Edition, Offprint Issue** of Pauli's paper on gas degeneracy and paramagnetism—"the point of departure for the modern electron theory of metals" (Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* p. 122). In the paper Pauli derived what is now known as Pauli paramagnetism, which Wikipedia defines as follows:

> For some alkali metals and noble metals, conduction electrons are weakly interacting and delocalized in space forming a Fermi gas. For these materials one contribution to the magnetic response comes from the interaction between the electron spins and the magnetic field known as Pauli paramagnetism.

About this paper, Pauli's student and assistant Rudolf Peierls stated that "it is probably no exaggeration to say that the modern electron theory of metals was started by Pauli's paper on the paramagnetism of an electron gas" (quoted in Enz, "W. Pauli's scientific work," p. 782).

Pauli presented this copy to Dutch physicist H. A. Kramers, one of the main architects, together with Pauli, Heisenberg and Schrödinger, of quantum mechanics. Pauli's inscription can be translated as "To my dear Kramers with warmest regards! Many thanks for your card!" Enz, "W. Pauli's scientific work," in J. Mehra, ed., *The Physicist's Conception of Nature,* pp. 766-799. 45904

**182. Pauli, Wolfgang** (1900-1958). Über das *H*-Theorem vom Anwachsen der Entropie vom Standpunkt der neuen Quantenmechanik. Offprint from P. Debye, ed., *Probleme der modernen Physik: Arnold Sommerfeld zum 60. Geburtstag gewidmet* (Leipig: S. Hirzel, 1928). 30-45pp. 243 x 170 mm. Without wrappers as issued. Signatures separated, last leaf detached. Good copy. From the library of H. A. Kramers (1894-1952), with his stamp on the first page. $1500

**First Edition, Offprint Issue.** Pauli's paper gives a quantum-mechanical treatment of irreversible processes (entropy), in particular Boltzmann's *H*-theorem proving the second law of thermodynamics. He discussed his approach in a letter to Bohr dated 16b June 1928, just before he started writing the present paper:

> Stimulated by our conversations during my last visit to Copenhagen on the problem of the uni-direction of the arrow of time, I have recently thought somewhat about the question: under what condition and in which generality may an "*H*-theorem" about increasing entropy be derived from the new quantum mechanics? . . . Now I believe that I am able to give the following answer to the problem of the *H*-theorem":
>
> 1. One can demonstrate the increase of entropy quite generally, that is, not only for special systems (such as the ideal gas) but independent of their specific composition.
>
> 2. However, one *still cannot* dispense with the particular assumption concerning "disordering"—in contrast to my original hope. This assumption, corresponding to the *Stoßzahlansatz* in classical mechanics, can be formulated in wave mechanics always in such a way that the *phases* of certain groups of eigenvibrations are independent of each other. I shall try in the next few days to write up the thing . . . (quoted in Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, p. 447).

This copy is from the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory. 50941

**183. Pauli, Wolfgang** (1900-1958). Diracs Wellengleichung des Elektrons und geometrische Optik. Offprint from *Helvetica physica acta* 5 (1932). 179-199pp. 231 x 158 mm. Without wrappers as issued. Light dust-soiling but very good to fine. $1500

**First Edition, Offprint Issue.** "In spring 1932 the Dirac equation [of the electron] was very much on Pauli's mind. One aspect he analyzed was the limit of short wavelengths, which is the analogue of the geometrical orbits of light rays and describes the limit of classical orbits. In this limit he could confirm Bohr's claim that the effect of the electron spin is of the same order of magnitude as that of diffraction, and that therefore spin is essentially non-classical. This paper, in which he also discussed the states of negative energy, was the first Pauli published in the new Swiss journal *Helvetica Physica Acta*" (Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli*, p. 253). 50942

**184. Pauli, Wolfgang** (1900-1958) and **Jacques Solomon** (1908-42). (1) La théorie unitaire d'Einstein et Mayer et les équations de Dirac. (2) La théorie unitaire d'Einstein et Mayer et les équations de Dirac (II). Together two offprints from *Le journal de physique et le radium*, series 7, 3 (1932). 452-463; 582-589pp. 272 x 184 mm. Original printed wrappers, somewhat sunned, a few chips, light creasing. Very good. $1750

**First Editions, Offprint Issues**. Pauli and Solomon's paper examines Einstein and Mayer's attempt at a unified field theory of the gravitational and electromagnetic fields, which the latter two authors had published in their paper "Einheitlichliche Theorie von Gravitation und Elektrizität" (1931). Pauli had been working a new collaborator, the Parisian physicist Jacques Solomon, and in the winter of 1931-32 he put Solomon onto the unified field theory problem. Solomon completed a paper on the subject, which he submitted to the *Journal de physique et le radium* under both his and Pauli's names; however, when Pauli asked his assistant Hendrik Casimir to read a proof of the paper, Casimir found that most of the essential formulae were wrong. "Pauli cabled to Paris that the paper had to be rewritten. But the editor of *Journal de physique,* Jean Langevin, who happened to be Solomon's brother-in-law, told Pauli with apologies that the second proofs had not come back in time. So the paper 'The unified theory of Einstein and Mayer and the Dirac equations' appeared uncorrected . . . Therefore Pauli decided to write a second paper with the same title, and Solomon had the benefit of two publications with the master" (Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli*, pp 265-266). 50930

**185. Pauli, Wolfgang** (1900-1958). Ûber die Intensität der Streustrahlung bewegter freier Elektronen. Offprint from *Helvetica physica acta* 6 (1933). 279-286pp. Without wrappers as issued. 230 x 157 mm. Light toning but very good. $1500

**First Edition, Offprint Issue.** In the first part of 1933 Pauli and his assistant Hendrik Casimir held numerous discussions about how to modify the Klein-Nishina formula (giving the differential cross-section of photons scattered from a free electron) due to the effect of the state of the scattering electron. Both Pauli and Casimir delivered papers on their respective results at the 6 May meeting of the Swiss Physical Society. "In his paper Pauli thanks Heisenberg for the suggestion to test the Klein-Nishina formula in a special frequency limit. This test was negative so that, in his letter to Heisenberg of 2 June, Pauli claims the bottle of Mosel wine they had bet" (Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli*, p. 271). 50945

**186. Pauli, Wolfgang** (1900-1958). Einige die Quantenmechanik betreffenden Erkundigsfragen. Offprint from *Zeitschrift für Physik* 80 (1933). 573-586pp. 230 x 156 mm. Original printed wrappers, slightly toned. Fine. $1500

**First Edition, Offprint Issue.** In 1932 Paul Ehrenfest, one of the early contributors to quantum theory, published a paper in the *Zeitschrift für Physik* titled "Einige die Quantenmechanik betreffenden Erkundigsfragen," in which he posed several so-called "senseless questions" about quantum mechanics—in the hope 'that there are still some researchers who understand the art of answering 'senseless' questions meaningfully and in a clear and simple matter.' To Pauli Ehrenfest's paper was 'a source of sheer pleasure'" (Enz, p. 256). Pauli addressed Ehrenfest's questions in the present paper, which bears the same title as Ehrenfest's; acknowledging that he himself had "partially hit upon some quite similar questions," he analyzed the following three queries: "1. On the role of the imaginary unit and the notion of the spatial density of a particle in wave mechanics; 2. The questions of the analogy between photons and electrons and of its limits and 3. On the question whether quantum mechanics may be expressed as a field theory" (Enz, p. 257). Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* pp. 256-257. 50943

**187. Pauli, Wolfgang** (1900-1958) and **Victor Weisskopf** (1908-2002). Über die Quantisierung der skalaren relativistischen Wellengleichungen. Offprint from *Helvetica physica acta* 7 (1934). 709-731pp. 230 x 157 mm. Without wrappers as issued. Small marginal tear in first leaf, light soiling. Very good. From the library of H. A. Kramers (1894-1952), with his name in pencil on the first leaf and annotations on pp. 712-713. $2750

**First Edition, Offprint Issue** of Pauli and Weisskopf's "anti-Dirac" paper, an important steppingstone to Pauli's famous demonstration of the relation between spin and statistics; the paper is one of eleven featured in A. I. Miller's *Early Quantum Electrodynamics: A Source Book* (1994). Seeking an alternative to Dirac's "holes" theory of the electron and positron, which he found highly objectionable, Pauli applied his and Heisenberg's "old formalism of field quantization" to the Klein-Gordon relativistic wave equation, which led "without any further hypothesis (without 'hole' idea, without limiting acrobatics, without subtraction physics!) to the existence of positrons and to processes of pair production with easily calculable frequency" (Pauli's 14 June 1934 letter to Heisenberg, quoted in Miller, p. 70). As Weisskopf later recalled,

> . . . at the time the method of exchanging the creation and destruction operators (for negative energy states) was not yet in fashion; [Dirac's] hole theory of the filled vacuum was still the accepted way of dealing with positrons. Pauli called our work the "anti-Dirac paper." He considered it a weapon in the fight against the

> filled vacuum that he never liked. We thought that this theory only served the purpose of a nonrelativistic example of a theory that contained all the advantages of the hold theory without the necessity of filling the vacuum. We had no idea that the world of particles would abound with spin-zero entities a quarter of a century later" (quoted in Mehra and Rechenberg, *The Historical Development of Quantum Theory,* 6, p. 942n).

This copy of Pauli and Weisskopf's paper is from the library of Dutch physicist H. A. Kramers, one of the major contributors to quantum theory; pp. 712-713 contain pencil annotations in Kramers's hand. Miller, "Frame-setting essay," in *Early Quantum Electrodynamics: A Source Book,* pp. 3-118; see pp. 188-205 of Miller's work for an English translation of Pauli and Weisskopf's paper. 50944

**188. Pauli, Wolfgang** (1900-1958) and **Morris E. Rose** (1911-67). Remarks on the polarization effects in the positron theory. Offprint from *The Physical Review* 49 (1936). 462-465pp. 267 x 201 mm. Original printed wrappers, slightly sunned, light creasing. Very good. $750

**First Edition, Offprint Issue.** "In January 1936, while at the Institute for Advanced Study in Princeton, Pauli submitted a paper that he wrote with Morris Erich Rose, in which they simplified the calculation of the additional current density in the Dirac-Heisenberg [positron] theory" (Mehra & Rechenberg, *The Historical Development of Quantum Theory*, 6, p. 920(n). 50946

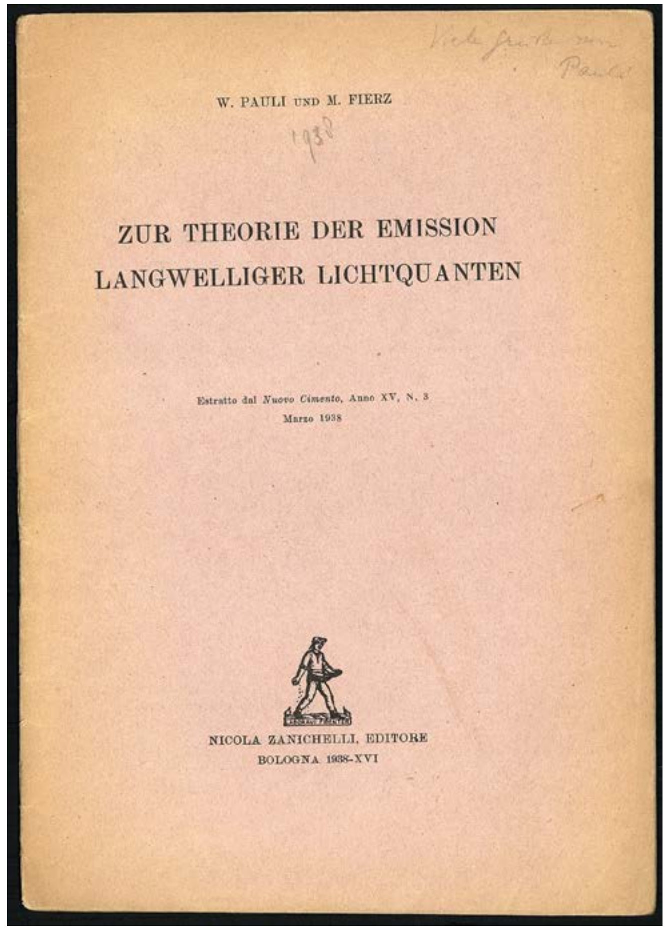
**189. Pauli, Wolfgang** (1900-1958) and **Markus Fierz** (1912-2006). Über das *H*-Theorem in der Quantenmechanik. Offprint from *Zeitschrift für Physik* 106 (1937). 572-587pp., plus mimeograph typescript errata slip laid in. 230 x 156 mm. Original printed front wrapper (detached, chipped), back wrapper lacking, minor soiling and wear. Good copy. From the library of H. A. Kramers (1894-1952), with his signature and stamp on the front wrapper and pencil notes on several pages, including the errata slip. $750

**First Edition, Offprint Issue.** In this paper Pauli and his assistant Fierz "took up the problem of Boltzmann's *H*-theorem in quantum mechanics that [Pauli] had analyzed in his contribution to Sommerfeld's 60th birthday celebration in 1928, now replacing the random phase assumption by the notion of the macro-observer who is able to observe only a coarse-grained density in phase space" (Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* p. 317). This copy is from the library of Dutch physicist H. A. Kramers, one of the major architects of quantum theory; his annotations appear on pages 575, 577, 580-581, and the errata slip. 50947

**190. Pauli, Wolfgang** (1900-1958). On asymptotic series for functions in the theory of diffraction of light. Offprint from *Physical Review* 54 (1938). 268 x 203 mm. Without wrappers as issued. Creased horizontally, some marginal fraying and chipping, first and last leaves sunned. Good copy. $500

**First Edition, Offprint Issue.** In 1938 Arnold Sommerfeld, Pauli's former teacher, celebrated his 70th birthday. "For this occasion a special issue of the *Annalen der Physik* was planned, which, however, was restricted to contributions from 'Aryan' authors. So Pauli and many other of Sommerfeld's pupils living abroad published an issue of the *Physical Review*; Pauli's contribution was about one of Sommerfeld's favorite subjects in optics" (Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* p. 322). 50949

## *"A New Direction in Quantum Electrodynamics"*




**191. Pauli, Wolfgang** (1900-1958) and **Markus Fierz** (1912-2006). Zur Theorie der Emission langwelliger Lichtquanten. Offprint from *Nuovo cimento* 15 (1938). 22pp. 244 x 172 mm. Original printed wrappers, a bit sunned. Very good. *Presentation Copy,* inscribed in pencil on the front wrapper: "Viele Grüße von Pauli."

$5000

**First Edition, Offprint Issue** of Pauli and Fierz's paper on the problem of infrared radiation in quantum electrodynamics—one of eleven featured in A. I. Miller's *Early Quantum Electrodynamics: A Source Book*.

Bloch and Nordsieck had previously addressed the problem of infrared radiation in quantum electrodynamics in a paper published in 1937. Not satisfied with Boch and Nordsieck's results, Pauli and his assistant Fierz set out to rework the problem more rigorously. "**Their methods demonstrate a new direction in quantum electrodynamics**" (Miller, p. 82; emphasis ours). "Pauli and Fierz, in a classic paper in 1938, further clarified the connection between Bloch and Nordsieck's and the classical description of the 'infrared' radiation. A freely moving electron is accompanied by its appropriate electromagnetic fields. In the classical theory these attached fields correspond to the Lienard-Wiechert potentials . . . in QED the 'attached' photons give rise to these electric and magnetic fields. As an important byproduct of their analysis, Pauli and Fierz, in their nonrelativistic model of 1938, recognized that the fields which accompany the charged particle react back on it to produce an electromagnetic mass. They identified the sum of the particle's mechanical mass and of its electromagnetic mass with the observed, experimental mass of the electron. Kramers at precisely this same period attempted to give a formulation of the quantum electrodynamics of extended nonrelativistic charged particles in which the structure and finite extension of the particles would not appear explicitly . . . **The concept of mass renormalization in QED has its origins in these researches of Pauli and Fierz** and of Kramers" (Schweber, *QED and the Men Who Made It*, p. 89; emphasis ours). Miller, "Frame-setting essay," in A. I. Miller, *Early Quantum Electrodynamics: A Source Book*, pp. 3-118; Pauli and Fierz's 1938 paper is one of eleven featured in Miller's *Early Quantum Electrodynamics: A Source Book* (pp. 227-243). 50929

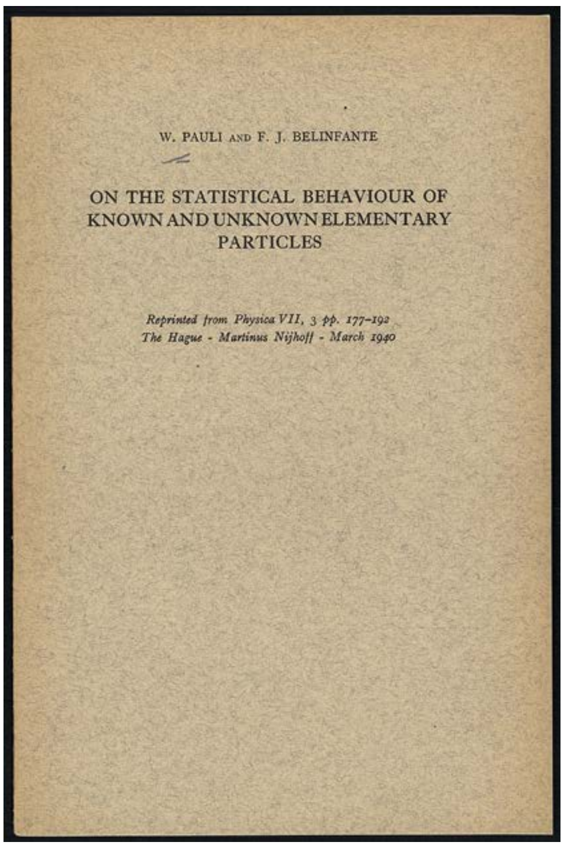
**192. Pauli, Wolfgang** (1900-1958). Über ein Kriterium für Ein- oder Zweiwertigkeit der Eigenfunktionen in der Wellenmechanik. Offprint from *Helvetica physica acta* 12 (1939). 147-168pp. 231 x 158 mm. Without wrappers as issued. Minor staining but very good. $600

**First Edition, Offprint Issue.** Pauli's paper, "On a criterion for single- or double-valuedness of the eigenfunctions in wave mechanics," showed "the possibility of double-valued wave functions which give rise to half-integer angular momentum states" (Giulini, p. 54). The paper was submitted to the *Helvetica physica acta* on 22 December 1938. Giulini, "Concepts of symmetry in the work of Wolfgang Pauli," in Atmanspacher and Primas, eds., *Recasting Reality: Wolfgang Pauli's Philosophical Ideas and Contemporary Science,* pp. 33-82. 50948

**193. Pauli, Wolfgang** (1900-1958) and **Markus Fierz** (1912-2006). Über relativistische Feldgleichungen von Teilchen mit beliebigem Spin im elektromanetischen Feld. Offprint from *Helvetica physica acta* 12 (1939). 297-300pp. 231 x 158 mm. Without wrappers as issued. Slight soiling and wear but very good. $500

**First Edition, Offprint Issue.** Pauli and Fierz's report to the Swiss Physical Society on the work they had been doing to address some of the difficulties with Dirac's relativistic wave equations. Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* p. 328. 50950

**194. Pauli, Wolfgang** (1900-1958) and **Frederick J. Belinfante** (1913-91). On the statistical behaviour of known and unknown elementary particles. Offprint from *Physica* 7 (1940). 177-192pp. 244 x 160 mm. Original printed wrappers, slightly sunned. Very good. $2750




**First Edition, Offprint Issue** of Pauli and Belinfante's paper on the relation of spin and statistics, which appeared the same year that Pauli published his famous spin-statistics theorem. "While Pauli and Fierz [in their 1939 paper] tried to cope with the extra, negative-energy particles—they especially formulated conditions to suppress these objects . . . Belinfante, a student of Hendrik Kramers's, entered into the fray by applying certain new mathematical methods and physical concepts in the theory of elementary particles; in particular he introduced—instead of the well-known tensor and spin calculus—a different scheme of mathematical quantities, which he called 'undors' and which could describe both integral-spin and half-integral spin fields . . . In the following investigation, 'On the Statistical Behaviour of Known and Unknown Elementary Particles,' (submitted in December 1939 and published in the March 1940 issue of *Physica,* the article having been written in English, with an abstract in German) Pauli and Belinfante joined forces. They first stated the three postulates which determined the statistics in the relativistic theories of (free) elementary particles, namely:

(I) The energy is always positive,

(II) Observables at different space-time points commute for space-like distances,

(III) There exist two equivalent descriptions of nature, in which the elementary charges have opposite sign, and in which corresponding field quantities transform in the same way under Lorentz transformations.

Pauli and Belinfante then demonstrated that, in the general case of undors having the same rank, postulate (III)—involving Belinfante's charge symmetrywould not suffice to determine the statistics of the associated particles; however, the postulates (I) or (II), respectively, would always do" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, pp. 960-961). 50951

**195. Pauli, Wolfgang** (1900-1958). Relativistic field theories of elementary particles. Offprint from *Reviews of Modern Physics* 13 (1941). 203-232pp. 268 x 201 mm. Original printed wrappers, slightly worn. Very good. $1500

**First Edition, Offprint Issue.** Pauli's extensive report on the relationship between spin and statistics, following the publication of his famous spin-statistics theorem in his 1940 paper, "The connection between spin and statistics." In the second part of the paper, Pauli discussed "the interaction of spin-0, spin-½, and spin-1 particles with an external electric field. Since his work with Fierz on this problem in 1939, several theoreticians in Europe and the United States had become interested in the electromagnetic properties of particles described by different relativistic wave equations, such as the cross sections of some electromagnetic processes involving charged particles of various spins. In his 1941 paper, Pauli thus summarized the status (achieved before the European War turned into World War II) of that aspect of elementary particle theory, which referred mainly to the consistent description of the properties of free elementary particles and their interaction with the external electromagnetic fields" (Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, 962). 50931

**196. Pauli, Wolfgang** (1900-1958) and **Shuichi Kusaka** (1915-47). On the theory of a mixed pseudoscalar and a vector meson field. Offprint from *The Physical Review* 63 (1943). 400-416pp. 267 x 199 mm. Original printed wrappers, two corners slightly bent, small rust stain on front wrapper. Very good to fine. $500

**First Edition, Offprint Issue.** Pauli's collaboration with Kusaka, a young Japanese-Canadian theoretical physicist, led to Pauli's second paper on strong-meson coupling theory, following his "On strong-coupling and weak-coupling theories of the meson field" (1943). "Apart from the nuclear force problem . . . , this paper contains a detailed spectroscopic analysis of the deuteron in the symmetrical pseudoscalar theory, as well as a calculation of the deuteron magnetic moment. The result for the latter is deceiving: only a small 'orbital' contribution is obtained. Thus, again, strong coupling gave no satisfactory results" (Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* p. 374). 50933

**197. Pauli, Wolfgang** (1900-1958). On applications of the λ-limiting process to the theory of the meson field. Offprint from *The Physical Review* 64 (1943). 332-344pp.268 x 200 mm. Original printed wrappers, one corner slightly bent. Very good. $500

**First Edition, Offprint Issue.** The λ-limiting process, a relativistically invariant regularization procedure applied to electromagnetic interactions, was introduced in the 1930s by Wentzel and Dirac. Pauli here applied it to meson theory, after having noted earlier that "such a weak coupling theory with point sources avoids all difficulties of the strong coupling theory with extended source" (quoted in Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* p. 379). 50934

**198. Pauli, Wolfgang** (1900-1958). On Dirac's new method of field quantization. *Reviews of Modern Physics* 15, no. 3 (July 1943). Whole number. 175-207pp. 267 x 200 mm. Original printed wrappers, corners slightly bent. Very good. $500

**First Edition.** In his Bakerian Lecture of 1941, Dirac addressed the problem of divergencies in existing quantum field theories by introducing "what amounts to photons of negative energy" (Pais, p. 24). Pauli was urged to write a review of Dirac's theory, but he at first demurred because he didn't think, as he wrote to Max Born in 1942, "that all the principal points are really clear enough" (Enz, p. 377). Pauli did eventually write a review, which was published as the July 1943 issue of *Reviews of Modern Physics*. "The principal merit of this paper is to have generalized Dirac's scalar product into a systematic treatment of an infinite metric in Hilbert space to handle negative probabilities. In the early 1950s this formalism became very important indeed" (Enz, p. 378). Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* pp. 377-378. Pais, "Paul Dirac: Aspects of his life and work," in *Paul Dirac: The Man and His Work,* ed. P. Goddard, pp. 1-45. 50932

**199. Pauli, Wolfgang** (1900-1958) and **Hu Ning** (1916-97). On the strong coupling case for spin-dependent interactions in scalar- and vector-pair theories. Offprint from *Reviews of Modern Physics* 17 (1945). 267-286pp. 267 x 199 mm. Original printed wrappers, upper margin slightly creased. Very good. $450

**First Edition, Offprint Issue.** Pauli collaborated with Hu, a Chinese physicist who had obtained his doctorate at Cal Tech, "on a systematic investigation of meson pairs in strong coupling . . . For Pauli the paper with Hu rounded off his activity in meson theory, which he found 'to be a bit exhausted now'" (Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli*, p. 383). 50935

**200. Pauli, Wolfgang** (1900-1958). Niels Bohr on his 60th birthday. Offprint from *Reviews of Modern Physics* 17 (1945). 97-101pp. 268 x 198 mm. Original printed wrappers, slightly dust-soiled. Very good to fine. $100

**First Edition, Offprint Issue.** 50936

**201. Pauli, Wolfgang** (1900-1958). Remarks on the history of the exclusion principle. In *Science* 103 (1946): 213-215. Whole number. 8, 213-240, 9-20pp. 262 x 189 mm. Original printed wrappers, vertically creased, light toning. Very good. $125

**First Edition,** journal issue of the address Pauli gave at a dinner held at the Institute for Advanced Study to honor his receipt of the Nobel Prize. 50940

**202. Pauli, Wolfgang** (1900-1958). Difficulties of field theories and of field quantization. Offprint from *Physical Society Cambridge Conference Report* (1947). 5-10pp. 262 x 181 mm. Without wrappers as issued. Light toning but very good. $375

**First Edition, Offprint Issue.** In July 1946 the first postwar gathering of European physicists took place at an international conference on "Fundamental Particles and Low Temperature," held at the Cavendish Laboratory at the University of Cambridge. Pauli's paper on the difficulties of field theories, delivered at the conference, reviewed the methods of the λ-limiting process and Dirac's negative probabilities, then went on to discuss Heisenberg's *S*-matrix. Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* pp. 409-410. Schweber, *QED and the Men Who Made It,* p. 153. 50937

**203. Pauli, Wolfgang** (1900-1958) and **Felix Vilars** (1921-2002). On the invariant regulation in relativistic quantum theory. Offprint from *Reviews of Modern Physics* 21 (1949). 434-444pp. 268 x 198 mm. Original printed wrappers. Very good. $1500

**First Edition, Offprint Issue**. Publication of the Pauli-Villars regularization (P-V), an important principle in quantum theory. P-V, based on earlier work by Richard Feynman, Ernst Stueckelberg and Dominique Rivier, is a procedure that "isolates divergent terms from finite parts in loop calculations in field theory in order to renormalize the theory" (Wikipedia). Pauli and Villars's paper was a direct inspiration for Julian Schwinger's "On gauge invariance and vacuum polarization" (1951), his greatest and most-cited paper; Schwinger, one of the founders of modern quantum electrodynamics, shared the Nobel Prize with Feynman and Tomonaga in 1965. 50938

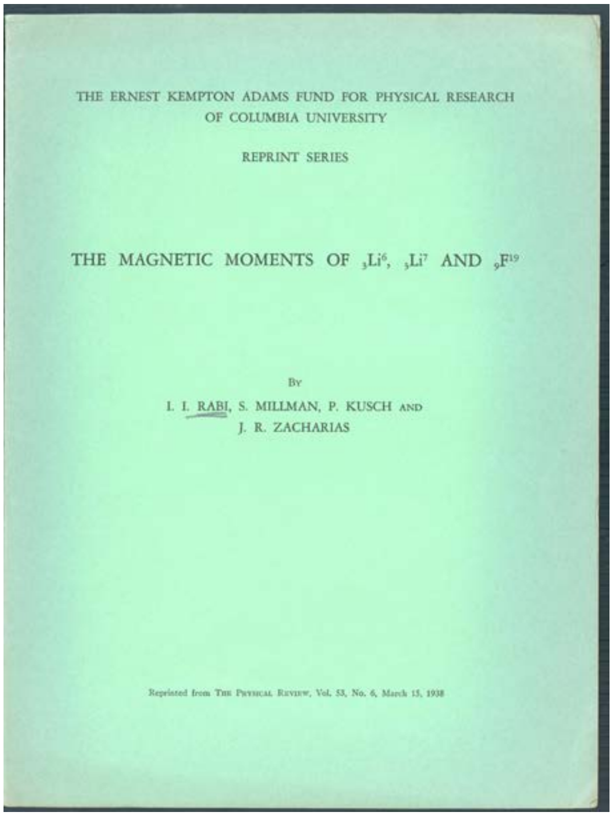
**204. Pauli, Wolfgang** (1900-1958). On the connection between spin and statistics. Offprint from *Progress of Theoretical Physics* 5 (1950). 526-543pp. 258 x 153 mm. Original printed wrappers, slightly soiled, small rust-stains. Very good. From the library of H. A. Kramers (1894-1952), with his pencil signature on the front wrapper. $1250

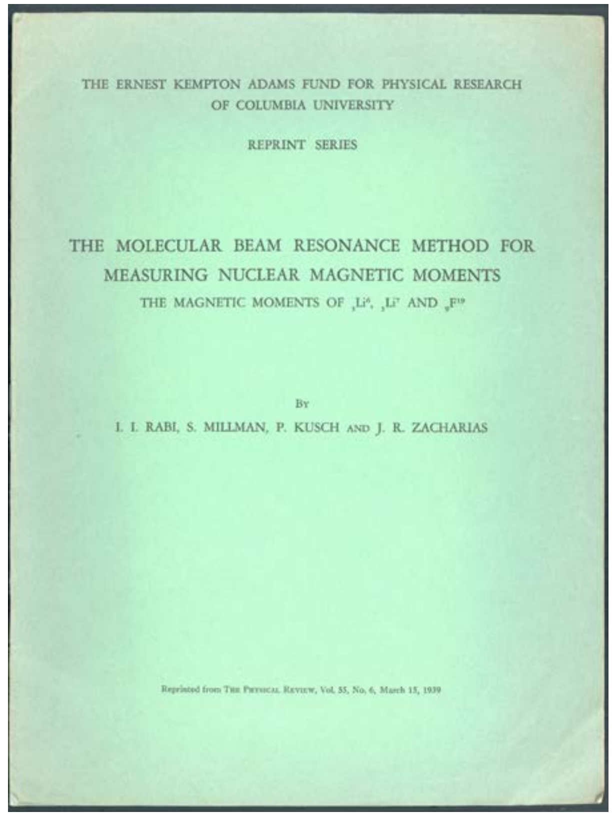
**First Edition, Offprint Issue.** Ten years after Pauli introduced his famous spin-statistics theorem ("The connection between spin and statistics" [1940]), he returned to the subject to respond to Feynman's observation that "the wrong statistics also work" (Enz, p. 336). "Pauli showed, for spin 0 and ½, that Feynman's treatment of the 'abnormal case' is equivalent to introducing negative probabilities and, hence, may be excluded by the condition that 'The metric in the Hilbert-space of the quantum mechanical states is positive definite" (*ibid.*). This copy of Pauli's paper is from the library of H. A. Kramers, one of the major architects of quantum theory. 50939

## *Pauli-Källén Equation*

**205. Pauli, Wolfgang** (1900-1958) and **A. O. Gunnar Källén** (1926-68). On the mathematical structure of T. D. Lee's model of a renormalizable field theory. Offprint from *Det Kongelige Danske Videnskabernes Selskab, Matematisk-fysiske Meddelelser,* 30 (1955). 23pp. 233 x 147 mm. Original printed wrappers. Fine. Stamp of CERN's Theoretical Study Division on the front wrapper. $500

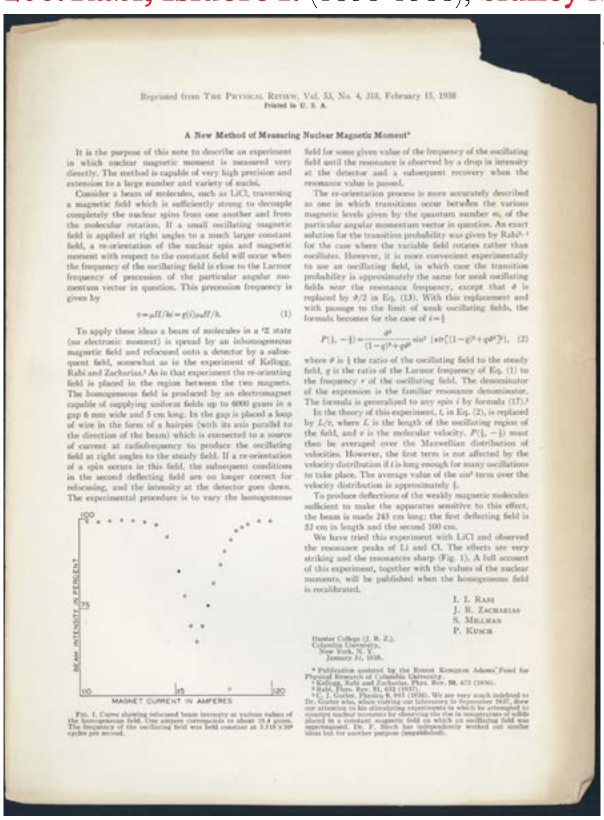
**First Edition, Offprint Issue.** In 1954 T. D. Lee, who would win the Nobel Prize in 1957, introduced his "Lee model," the first renormalizable quantum field theory for which exact solutions could be obtained. In April 1954 Lee gave a lecture on his model at Princeton, attended by both Pauli and the young Swedish theoretical physicist Gunnar Källén; afterwards Pauli and Källén exchanged a number of highly technical letters analyzing Lee's model, which resulted in the present paper. The paper contains the first publication of the Pauli-Källén equation for unstable particles in the Lee model. Enz, *No Time to be Brief: A Scientific Biography of Wolfgang Pauli,* p. 504. 50927




*Discovery of Nuclear Magnetic Resonance*

**206. Rabi, Isidore I.** (1898-1988); **Sidney Millman** (1904-2006); **Polykarp Kusch** (1911-93); **Jerrold R. Zacharais** (1905-86). (1) A new method of measuring nuclear magnetic moment. Offprint from *Physical Review* 53 (1938). Single sheet, unbound. 267 x 200 mm. Browned at edges, light fraying, piece missing from upper corner (not affecting text). (2) The magnetic moments of $_3Li^6$, $_3Li^7$, and $_9F^{19}$. Offprint from *Physical Review* 53 (1938). [1] page. 267 x 200 mm. Original printed wrappers, slightly sunned, Rabi's name underlined in pencil on front wrapper. (3) The molecular beam resonance method for measuring nuclear magnetic moments: The magnetic moments of $_3Li^6$, $_3Li^7$, and $_9F^{19}$. Offprint from *Physical Review* 55 (1939). 526-535pp. 267 x 200 mm. Original printed wrappers, slightly sunned, lower corner lightly creased. Together 3 items. Very good. $9500



Reprinted from THE PHYSICAL REVIEW, Vol. 53, No. 4, 318, February 15, 1938
Printed in U. S. A.

**A New Method of Measuring Nuclear Magnetic Moment***

It is the purpose of this note to describe an experiment in which nuclear magnetic moment is measured very directly. The method is capable of very high precision and extension to a large number and variety of nuclei.

Consider a beam of molecules, such as LiCl, traversing a magnetic field which is sufficiently strong to decouple completely the nuclear spins from one another and from the molecular rotation. If a small oscillating magnetic field is applied at right angles to a much larger constant field, a re-orientation of the nuclear spin and magnetic moment with respect to the constant field will occur when the frequency of the oscillating field is close to the Larmor frequency of precession of the particular angular momentum vector in question. This precession frequency is given by

$$\nu = \mu H/hi = g(i)\mu_0 H/h. \quad (1)$$

To apply these ideas a beam of molecules in a $^1\Sigma$ state (no electronic moment) is spread by an inhomogeneous magnetic field and refocused onto a detector by a subsequent field, somewhat as in the experiment of Kellogg, Rabi and Zacharias.[1] As in that experiment the re-orienting field is placed in the region between the two magnets. The homogeneous field is produced by an electromagnet capable of supplying uniform fields up to 6000 gauss in a gap 6 mm wide and 5 cm long. In the gap is placed a loop of wire in the form of a hairpin (with its axis parallel to the direction of the beam) which is connected to a source of current at radiofrequency to produce the oscillating field at right angles to the steady field. If a re-orientation of a spin occurs in this field, the subsequent conditions in the second deflecting field are no longer correct for refocusing, and the intensity at the detector goes down. The experimental procedure is to vary the homogeneous field for some given value of the frequency of the oscillating field until the resonance is observed by a drop in intensity at the detector and a subsequent recovery when the resonance value is passed.

The re-orientation process is more accurately described as one in which transitions occur between the various magnetic levels given by the quantum number $m$, of the particular angular momentum vector in question. An exact solution for the transition probability was given by Rabi[2, 3] for the case where the variable field rotates rather than oscillates. However, it is more convenient experimentally to use an oscillating field, in which case the transition probability is approximately the same for weak oscillating fields *near* the resonance frequency, except that $\vartheta$ is replaced by $\vartheta/2$ in Eq. (15). With this replacement and with passage to the limit of weak oscillating fields, the formula becomes for the case of $i=\frac{1}{2}$

$$P(\tfrac{1}{2},-\tfrac{1}{2}) = \frac{\vartheta^2}{(1-q)^2+q\vartheta^2}\sin^2\{\pi\nu t[(1-q)^2+q\vartheta^2]^{\frac{1}{2}}\}, \quad (2)$$

where $\vartheta$ is $\frac{1}{2}$ the ratio of the oscillating field to the steady field, $q$ is the ratio of the Larmor frequency of Eq. (1) to the frequency $\nu$ of the oscillating field. The denominator of the expression is the familiar resonance denominator. The formula is generalized to any spin $i$ by formula (17).[2]

In the theory of this experiment, $t$, in Eq. (2), is replaced by $L/v$, where $L$ is the length of the oscillating region of the field, and $v$ is the molecular velocity. $P(\frac{1}{2},-\frac{1}{2})$ must then be averaged over the Maxwellian distribution of velocities. However, the first term is not affected by the velocity distribution if $t$ is long enough for many oscillations to take place. The average value of the $\sin^2$ term over the velocity distribution is approximately $\frac{1}{2}$.

To produce deflections of the weakly magnetic molecules sufficient to make the apparatus sensitive to this effect, the beam is made 245 cm long; the first deflecting field is 52 cm in length and the second 100 cm.

We have tried this experiment with LiCl and observed the resonance peaks of Li and Cl. The effects are very striking and the resonances sharp (Fig. 1). A full account of this experiment, together with the values of the nuclear moments, will be published when the homogeneous field is recalibrated.

I. I. RABI
J. R. ZACHARIAS
S. MILLMAN
P. KUSCH

Hunter College (J. R. Z.),
Columbia University,
New York, N. Y.
January 31, 1938.

BEAM INTENSITY IN PERCENT: 100, 75
MAGNET CURRENT IN AMPERES: 10, 15, 20

FIG. 1. Curve showing refocused beam intensity at various values of the homogeneous field. One ampere corresponds to about 18.4 gauss. The frequency of the oscillating field was held constant at $3.518\times10^6$ cycles per second.

* Publication assisted by the Ernest Kempton Adams' Fund for Physical Research of Columbia University.
[1] Kellogg, Rabi and Zacharias, Phys. Rev. 50, 472 (1936).
[2] Rabi, Phys. Rev. 51, 652 (1937).
[3] C. J. Gorter, Physica 3, 995 (1936). We are very much indebted to Dr. Gorter who, when visiting our laboratory in September 1937, drew our attention to his stimulating experiments in which he attempted to measure nuclear moments by observing the rise in temperature of solids placed in a constant magnetic field on which an oscillating field was superimposed. Dr. F. Bloch has independently worked out similar ideas but for another purpose (unpublished).

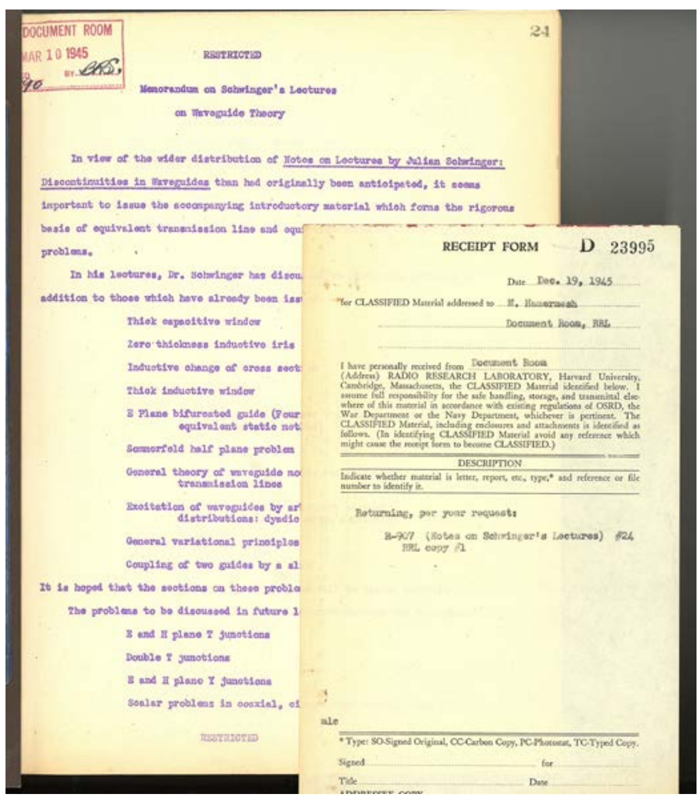
**First Editions, Offprint Issues** of Rabi's first papers on his resonance method of magnetic moment measurement, which earned him the Nobel Prize for physics in 1944. Rabi's resonance method is not only of central importance in physics, but is also the foundation of magnetic resonance imaging (MRI), which revolutionized medical imaging in the last decades of the twentieth century.

Rabi received his doctorate in physics from Columbia University in 1927 and afterwards traveled to Europe to study physics with Bohr, Pauli, Stern and Heisenberg. From Stern, Rabi learned the molecular-beam method, which appealed to him so much that he established his own molecular beam laboratory at Columbia in 1931, shortly after being appointed to the university's physics faculty. Over the next few years Rabi refined his molecular-beam apparatus, working with a team that included future Nobel Laureate Polykarp Kusch. In 1937, after learning of the failed attempts of Dutch physicist Cornelis Gorter to detect nuclear magnetic resonance in solid matter, the Rabi team began their experimental investigations in earnest. As Norman Ramsey, then one of Rabi's team members, writes:

> In September 1937, Gorter visited Rabi's laboratory at Columbia University and described his brilliantly conceived but experimentally unsuccessful efforts to observe resonant heating of a substance in a strong static magnetic field when also subjected to a weak field oscillating at the precession frequency of the nucleus in the static field. Rabi then fully appreciated the advantage of using an oscillatory field and promptly invented the molecular beam magnetic resonance method. Two successful molecular beam magnetic resonance apparatuses were soon constructed by Rabi, J. R. Zacharias, S. Millman, and P. Kusch, and by J. M. B. Kellogg, Rabi, Ramsey and Zacharias . . . As expected, the first magnetic resonance was observed by Rabi, Zacharias, Millman and Kusch, who were studying the easily detected LiCl molecule (Ramsey, p. 126).

In the spring of 1938 Rabi and his team published two short papers in the *Physical Review* (nos. [1] and [2] above) "report[ing] briefly on a new precision method of measuring nuclear moment, and on some results" (Rabi *et al.* [1939], p. 526). These were followed in 1939 by "The molecular beam resonance method for measuring nuclear magnetic moments: The magnetic moments of $_{3}\mathrm{Li}^{6}$, $_{3}\mathrm{Li}^{7}$, and $_{9}\mathrm{F}^{19}$" (no. [3] above), containing the first complete account of the Rabi team's magnetic resonance experiments. N. Ramsay, "Early history of magnetic resonance," *Phys. Perspectives* 1 [1999]: 123-135. Rabi's achievement is documented in detail in the first chapter of Mattson and Simon's *The Pioneers of NMR and Magnetic Resonance in Medicine: The Story of MRI* (1996). 46008

**207. Schwinger, Julian** (1918-94). Notes on lectures by Julian Schwinger: Discontinuities in waveguides. Prepared by David S. Saxon. Dittoed typescript, numbered "24", each leaf stamped "Confidential"; first leaf with Harvard. Radiation Research Laboratory Document Room stamp dated 10 March 1945. [3], xxviii, 109ff. 281 x 217 mm. In stiff binder with metal fasteners, handwritten paper label on the front cover, light wear. Very good. Laid in is a printed "Receipt form" dated 19 December 1945, completed in carbon typescript, showing that this copy had been signed out to Schwinger's sometime collaborator Morton Hamermesh (1915-2003). $2750




**First Printing.** Schwinger was one of the architects of modern quantum electrodynamics, receiving a share of the 1965 Nobel Prize in physics (together with Richard Feynman and Shin'ichiro Tomonaga) for his contribution to QED theory. QED, a synthesis of quantum field theory and special relativity, originated in the 1920s with the work of Heisenberg, Dirac, Pauli and other physicists as a means of describing the behavior of subatomic particles; by the 1940s, however, experimental anomalies and inherent mathematical errors were eroding faith in its validity. Schwinger helped to restore confidence in the theory by developing a method called "mathematical renormalization" to calculate the proper masses and charges of subatomic particles. "[Schwinger's] efforts culminated in the acceptance of quantum field theory as the proper representation of microscopic phenomena, and he was awarded the Nobel Prize for this achievement" (Schweber, *QED and the Men Who Made It,* p. 274).

During World War II Schwinger worked on radar and microwave technology at MIT's Radiation Laboratory, second only to the Manhattan Project in its size and importance to the U. S. war effort. Schwinger was put in charge of the waveguide theory team, responsible for designing the special metallic pipelines needed to conduct microwave energy with minimum loss. "Schwinger felt very comfortable with his assignment, which, because of sheer complexity, was intellectually challenging and matched well his background in electromagnetic interactions in quantum physics. Methodologically, the diffraction of electromagnetic waves resembled the scattering problems in quantum mechanics, so he would not stray too far from conceptually familiar territory . . . The experiences of the Radiation Laboratory turned out to be very stimulating for [Schwinger's] scientific career and there is no way of knowing what his life as a physicist would look like without them" (Mehra, *Climbing the Mountain: The Scientific Biography of Julian Schwinger,* p. 106).

The present notes on Schwinger's Rad Lab waveguide lectures, compiled by his colleague David A. Saxon (1920-2005), were initially marked "Restricted" when they were distributed; this classification was later lowered to "Confidential." This copy—copy no. 24—was at one time issued to Morton Hamermesh, who would later collaborate with Schwinger on the scattering of slow neutrons by ortho- and para-hydrogen and deuterium. 51017

**208. Schwinger, Julian** (1918-94). Atomic basis of the Maxwell equations. Reproduced typescript. 84ff. 280 x 218 mm. N.p., n.d. [1946]. In stiff folder with metal fasteners, typewritten label on front cover, some wear and fraying. Very good. $1750

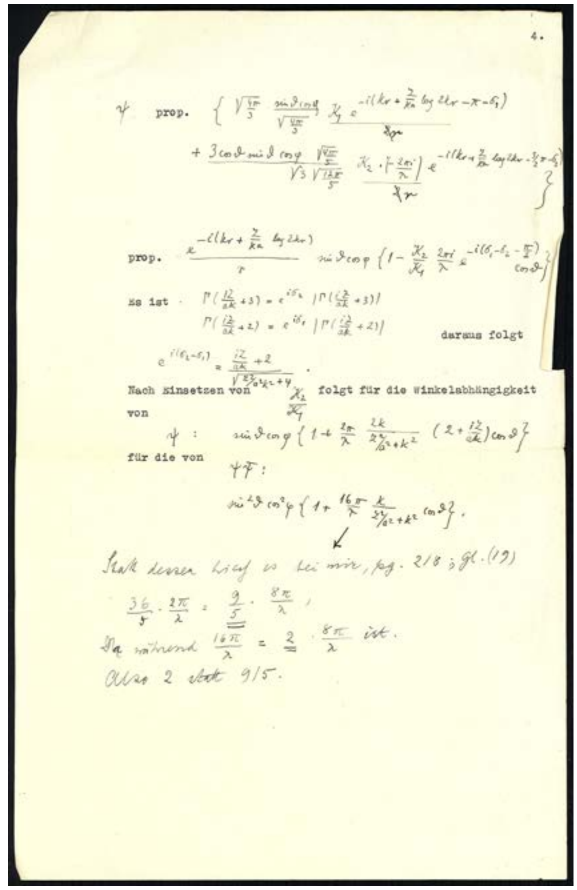
Unpublished lecture delivered at MIT's Radiation Laboratory just prior to his departure from the lab to join the physics faculty at Harvard. Portions of this lecture, reworked and augmented, were later incorporated into Milton and Schwinger's *Electromagnetic Radiation: Variational Methods, Waveguides and Accelerators* (2006), a graduate-level textbook based on Schwinger's wartime work at the Rad Lab.

Schwinger's lectures played an important role "as a means of disseminating his ideas to his entourage . . . Schwinger's beautifully prepared lectures were an inspiration to his students, as well as a constant source of surprise, because he would always take up topics which had emerged in his own research . . . For many years, those attending Schwinger's lectures were offered very precious and the latest unpublished information that almost nobody else anywhere had access to" (Mehra, *Climbing the Mountain: The Scientific Biography of Julian Schwinger,* p. 154). 51014

**209. Schwinger, Julian** (1918-94). On the properties of K-mesons. Reproduced (dittoed) typescript. 15ff. 282 x 218 mm. Unbound, stapled. From the library of Nobel Laureate Owen Chamberlain (1920-2006), with his signature on the first leaf. Light horizontal creases where previously folded, but very good. $2750

**Preprint Issue** of Schwinger's paper, published under the title "The dynamical theory of K mesons" in *Physical Review* 104 (1956). In the paper Schwinger argued that parity could not be violated; however, at this time C. N. Yang and T. D. Lee were testing the possibility that parity could be violated in weak interactions (the two later won the Nobel Prize for demonstrating that this was indeed the case). Schwinger, a theoretical physicist at Harvard University, was responsible for much of modern quantum field theory; he, Richard Feynman and Shinichiro Tomonaga received the Nobel Prize in 1965 for their work on quantum electrodynamics. See Mehra & Milton, *Climbing the Mountain: The Scientific Biography of Julian Schwinger*, pp. 415-418. Chamberlain, the former owner of this copy, shared the 1959 Nobel Prize in Physics with Emilio Segrè for the discovery of the antiproton. 43658

**210.** [**Sommerfeld, Arnold** (1868-1951).] **G. Schur.** Zusatz von G. Schur. Typescript with manuscript additions in Schur's and Sommerfeld's hands. 4ff. 333 x 210 mm. N.p., n.d. [ca. 1930]. Creased horizontally, right margin a bit frayed, small rust stain from paperclip. Very good. $4000



Original typescript, apparently unpublished, with manuscript title and note at the end in Sommerfeld's hand and manuscript equations in what is presumably Schur's hand; the title translates to "Addition by G. Schur." The typescript begins:

> Zur Berechnung der Einseitigkeit der Elektronenemission im Photoeffekt bei kurzwelligem Licht ist nach s. 216 wellenmechanischer ergänzungsband die Auswertung der Entwicklungskoeffizienten equation] . . . [In order to calculate the one-sidedness of the electron emission in the photo effect with short-wave light, it is necessary to evaluate the development coefficients (equation) according to p. 216 . . .]

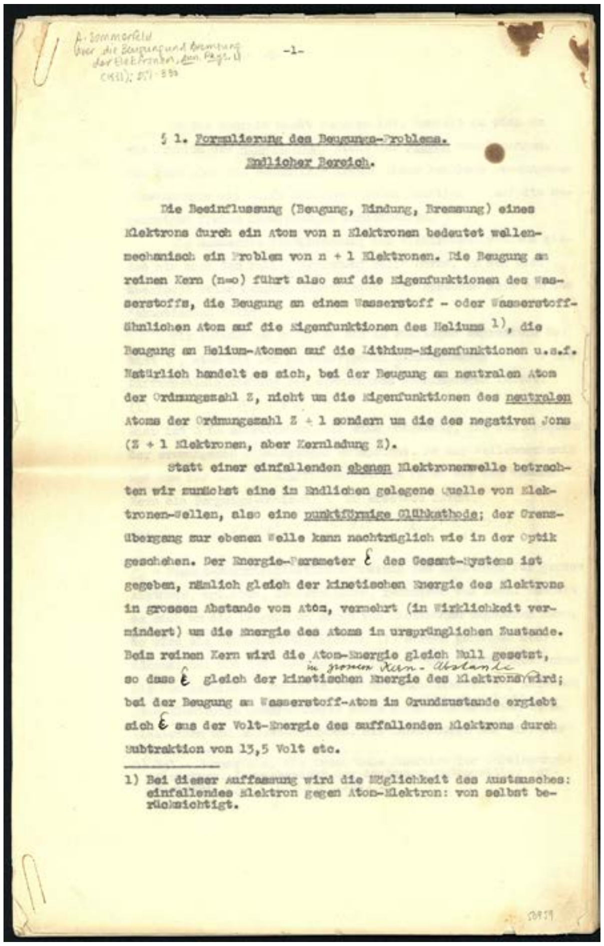
Sommerfeld's note at the end, correcting one of Schur's equations, reads: "Statt dessen hiess es bei mir, pg. 218; Gl. (19) , während ist. Also 2 statt 9/5." [Instead, I said, pg. 218; Eq. (19) while . So 2 instead of 9/5].

It is possible that the present typescript relates to Sommerfeld and Schur's paper titled "Über den Photoeffekt in der K-Schale der Atome, insbesondere über die Voreilung der Photoelektron" [On the photo effect in the K shell of the atom, in particular on the advance of the photo electron], published in *Annalen der Physik* 4 (1930): 409-432; see below. 50977

**211. Sommerfeld, Arnold** (1868-1951) and **G. Schur.** Über den Photoeffekt in der K-Schale der Atome, insbesondere über die Voreilung der Photoelektronen. Offprint from *Annalen der Physik*, 5th series, 4 (1930). 419-449pp. 225 x 145 mm. Without wrappers as issued. Small tears in paper backstrip, light toning but very good. $750

**First Edition, Offprint Issue**. "In 1929 Arnold Sommerfeld and G. Schur carried out a systematic wave mechanical calculation of the effect of radiation pressure (i.e., of the action of the electric and magnetic fields of the incident radiation) on the intensity distribution of the photoelectrons. In particular, they found that Wentzel's formula . . . which he had obtained by simply considering the momentum of the incident light-quantum—must be improved" (Mehra & Rechenberg, *Erwin Schrödinger and the Rise of Wave Mechanics,* p. 838[n]). Gregor Wentzel had published the formula in his paper "Über die Richtungsverteilung der Photoelektronen" (*Zeitschrift für Physik* 41 [1927]: 828-832). 50952

**212. Sommerfeld, Arnold** (1868-1951).] Formulierung des Beugungs-Problems. Endlicher Bereich. Carbon typescript with manuscript additions in Sommerfeld's hand. 29ff., numbered 1-27, 27a, 28. 330 x 210 mm. N.p., n.d. (1931). Creased horizontally, some minor marginal fraying and chipping, light soiling. Very good. $7500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§ 1. Formulierung des Beugungs-Problems. Endlicher Bereich.

Die Beeinflussung (Beugung, Bindung, Bremsung) eines Elektrons durch ein Atom von n Elektronen bedeutet wellenmechanisch ein Problem von n + 1 Elektronen. Die Beugung am reinen Kern (n=o) führt also auf die Eigenfunktionen des Wasserstoffs, die Beugung an einem Wasserstoff - oder Wasserstoff-ähnlichen Atom auf die Eigenfunktionen des Heliums 1), die Beugung an Helium-Atomen auf die Lithium-Eigenfunktionen u.s.f. Natürlich handelt es sich, bei der Beugung am neutralen Atom der Ordnungszahl Z, nicht um die Eigenfunktionen des neutralen Atoms der Ordnungszahl Z + 1 sondern um die des negativen Jons (Z + 1 Elektronen, aber Kernladung Z).

Statt einer einfallenden ebenen Elektronenwelle betrachten wir zunächst eine im Endlichen gelegene Quelle von Elektronen-Wellen, also eine punktförmige Glühkathode; der Grenzübergang zur ebenen Welle kann nachträglich wie in der Optik geschehen. Der Energie-Parameter ε des Gesamt-Systems ist gegeben, nämlich gleich der kinetischen Energie des Elektrons in grossem Abstande vom Atom, vermehrt (in Wirklichkeit vermindert) um die Energie des Atoms im ursprünglichen Zustande. Beim reinen Kern wird die Atom-Energie gleich Null gesetzt, so dass ε gleich der kinetischen Energie des Elektrons im grossen Kern-Abstande wird; bei der Beugung am Wasserstoff-Atom im Grundzustande ergiebt sich ε aus der Volt-Energie des auffallenden Elektrons durch Subtraktion von 13,5 Volt etc.

1) Bei dieser Auffassung wird die Möglichkeit des Austausches: einfallendes Elektron gegen Atom-Elektron: von selbst berücksichtigt.

Carbon typescript of a section of Sommerfeld's "Über die Beugung und Bremsung der Elektronen" (*Annalen der Physik* 11 [1931]: 257-330), **with numerous manuscript equations and other additions in Sommerfeld's hand;** the section title can be translated as "Formulation of the diffraction problem: Finite area." Sommerfeld's paper on the diffraction and slowing down of electrons is still cited in current publications on electron microscopy, cosmic ray physics, X-ray tube spectra and related subjects.

Sommerfeld, one of the pioneers of atomic and quantum physics, was a brilliant theoretician who introduced the second (azimuthal) quantum number and the fine-structure constant, and pioneered X-ray wave theory. His application of Bohr's revolutionary 1913 theory of the atom to the Zeeman effect and to the fine structure of spectral lines was largely responsible for the rapid and widespread acceptance of Bohr's atomic model. The results of Sommerfeld's investigations of atomic spectra and the Zeeman effect performed during the 1910s and 1920s were accepted almost without change in the post-1925 quantum-mechanical theory of atomic structure. Sommerfeld was equally brilliant as an educator: As the director of the University of Munich's Theoretical Physics Institute, Sommerfeld taught and mentored many of the creators of the new quantum physics, including Nobel Laureates Werner Heisenberg and Wolfgang Pauli. 50959

**213. Sommerfeld, Arnold** (1868-1951). Über die elektromagnetischen Einheiten. Offprint from *Peter Zeeman 1865-1935: Verhandelingen op 25 Mei 1935 aangeboden aan Professor Dr. P. Zeeman* (The Hague: Nijhoff, 1935). 157-165pp. 243 x 162 mm. Original printed wrappers, margins sunned. Very good. *Presentation Copy,* inscribed by Sommerfeld to Gregor Wentzel (1898-1978) on the front wrapper: "Gruss u. Dank! A. S."; Wentzel's name in ink in a different hand over Sommerfeld's inscription. $1250

**First Edition, Offprint Issue.** Gregor Wentzel, who made notable contributions to quantum mechanics, had served for a time as Sommerfeld's assistant. 50956

**214. Sommerfeld, Arnold** (1868-1951) and **Fritz Renner** (1907-98). Strahlungsenergie und Erdabsorption bei Dipolantennen. Offprint from *Annalen der Physik*, 5th series, 41 (1942). 36pp. 231 x 155 mm. Without wrappers as issued. Slight toning but very good. *Presentation Copy,* inscribed by Sommerfeld to Gregor Wentzel (1898-1978) on the first page: "G. L. Wentzel von A. S." $1250

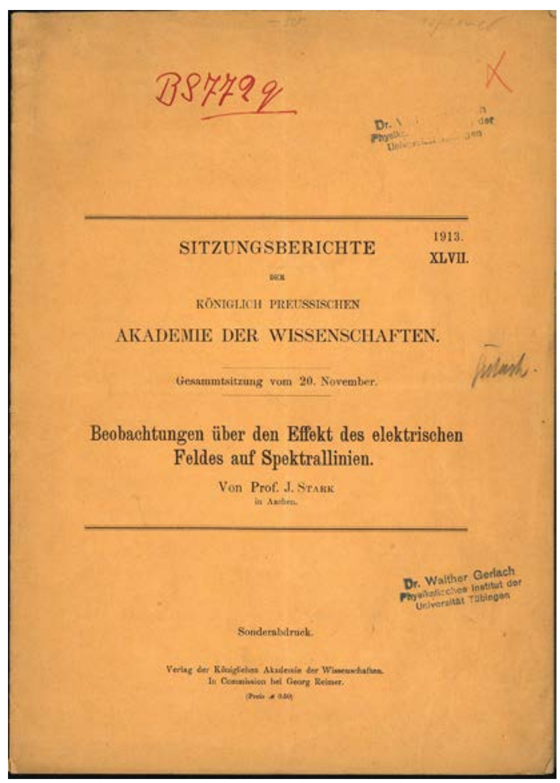
**First Edition, Offprint Issue.** During World War II Germany's NVK (Signals Experimental Command), on behalf of the German Navy, asked Sommerfeld to calculate "the effects of the Earth's curvature on the propagation of electromagnetic waves and their refraction in the upper atmosphere. Sommerfeld left the calculations involved to Renner, his assistant, and limited himself to indicating the approach used in each case . . . the Navy seems not to have ranked the importance of their work very highly, for Sommerfeld and Renner were put under no particular time pressure and were even permitted to publish portions of their results" (Eckert, *Arnold Sommerfeld: Science, Life and Turbulent Times 1868-1951*, p. 389). Somme1250rfeld presented this copy to theoretical physicist Gregor Wentzel, who made notable contributions to quantum mechanics; Wentzel had served for a time as Sommerfeld's assistant. 50954

**215. Sommerfeld, Arnold** (1868-1951). Die frei schwingende Kolbenmembran. Offprint from *Annalen der Physik*, 5th series, 42 (1943). 389-420pp. 230 x 156 mm. Without wrappers as issued. Slightly sunned, but very good. *Presentation Copy,* inscribed by Sommerfeld to Gregor Wentzel (1898-1978) on the first page: "G. L. G. Wentzel mit frdl. Gruss vom Verf." $1250

**First Edition, Offprint Issue.** Sommerfeld's theory of the freely vibrating piston diaphragm. "The problem had presumably arisen in the context of 'questions of underwater noise,' which Fritz Renner, commissioned by the [German] Navy's Experimental Telecommunications Command (Nachrichtenmittel-Versuchskommando), had worked up before being requisitioned by Sommerfeld as his assistant. In this case, though, it was less the physics associated with the problem that made this an interesting case for Sommerfeld, than the mathematical treatment. In studying more closely the pertinent technical literature on acoustics, he found that a procedure for solving the boundary value problem in question which to him seemed particularly useful appeared to be unknown in that domain" (Eckert, *Arnold Sommerfeld: Science, Life and Turbulent Times 1868-1951*, p. 413). Sommerfeld presented this copy to theoretical physicist Gregor Wentzel, who made notable contributions to quantum mechanics; Wentzel had served for a time as Sommerfeld's assistant. 50955

## *The Stark Effect—Nobel Prize-Winning Discovery*

**216. Stark, Johannes** (1874-1957). Beobachtungen über den Effekt des elektrischen Feldes auf Spektrallinien. Offprint from *Sitzungsberichte der königlich preussischen Akademie der Wissenschaften* 47 (1913). 932-946pp. 253 x 180 mm. Original printed wrappers, creased vertically and horizontally, light soiling. Very good. From the library of Walther Gerlach (), with his pencil signature and ownership stamp on the front cover and occasional pencil notes in the text; a pencil drawing on the back wrapper is also probably his. $7500

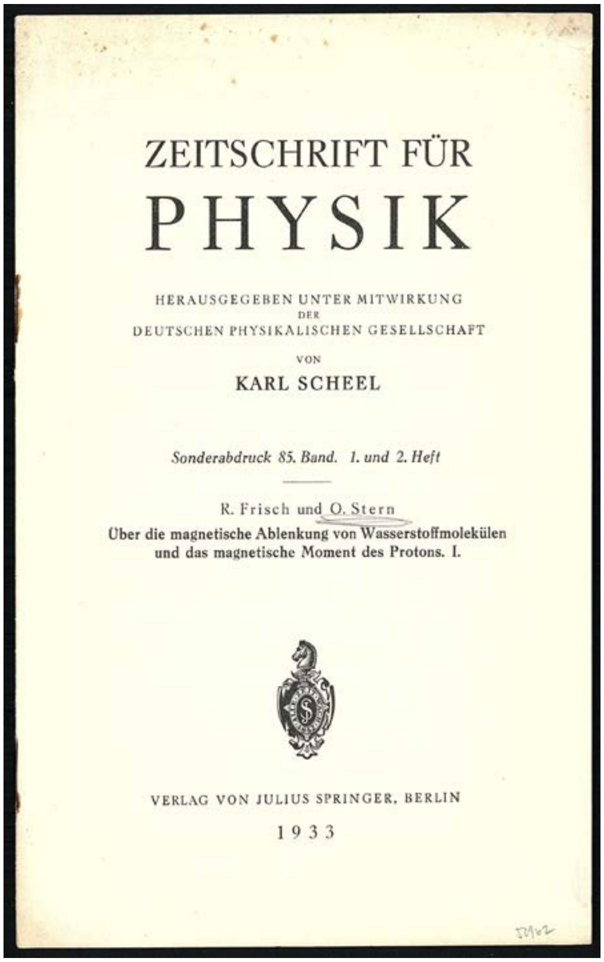



**First Edition, Offprint Issue.** Stark received the Nobel Prize in 1919 for the discovery of the Doppler effect in canal rays and for his discovery of the "Stark effect"—the splitting of spectral lines in an electric field (1913)—which was later incorporated into both quantum and wave mechanics. Stark was one of the most effective early advocates of quantum theory, publishing a large number of papers on the subject, and founding the *Jahrbuch der Radioaktivität und Elektronik* in 1904 to spread word about new developments in physics, particularly particle physics. He remained in the forefront of research in this area until 1913, when he inexplicably turned against both quantum theory and the general theory of relativity.

This copy is from the library of Walther Gerlach, co-discoverer of spin quantization in a magnetic field (the "Stern-Gerlach" effect). Gerlach annotated this copy in pencil on pp. 936 and 940-942; the pencil drawing on the back wrapper (based on the illustration on p. 934) is also probably his. *Dictionary of Scientific Biography.* Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 1, p. 110(n). 51001

## *First Measurement of the Proton Magnetic Moment*

**217. Stern, Otto** (1888-1969); **Otto Robert Frisch** (1904-79) Über die magnetische Ablenkung von Wasserstoffmolekülen und das magnetische Moment des Protons. I. Offprint from *Zeitschrift für Physik* 85 (1933). 4-16pp. Original printed wrappers, slightly spotted. Very good. $3750

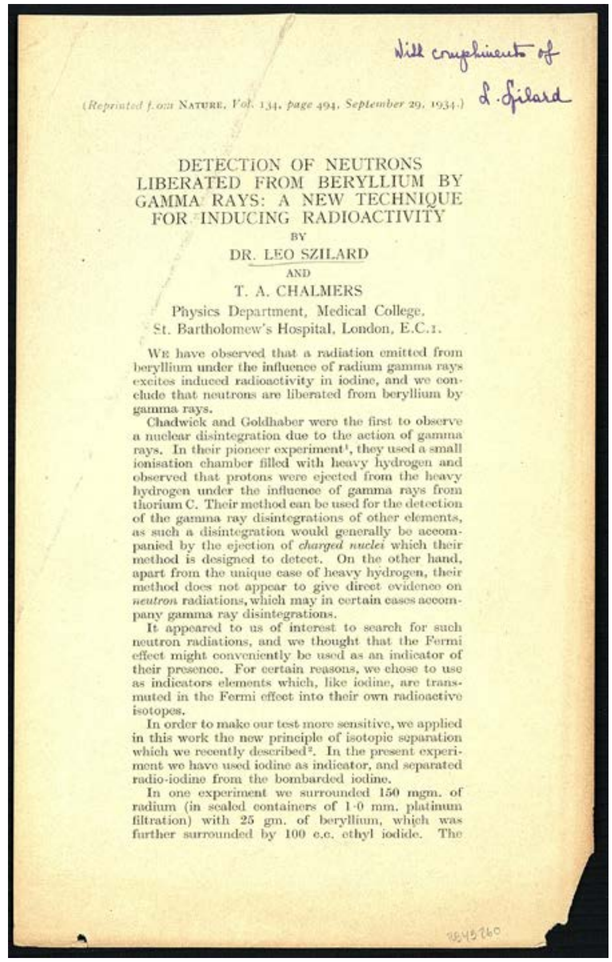

ZEITSCHRIFT FÜR
PHYSIK
HERAUSGEGEBEN UNTER MITWIRKUNG
DER
DEUTSCHEN PHYSIKALISCHEN GESELLSCHAFT
VON
KARL SCHEEL
Sonderabdruck 85. Band. 1. und 2. Heft
R. Frisch und O. Stern
Über die magnetische Ablenkung von Wasserstoffmolekülen
und das magnetische Moment des Protons. I.
VERLAG VON JULIUS SPRINGER, BERLIN
1933

**First Edition, Offprint Issue.** Using the molecular beam method he had developed in the 1920s, Stern and his collaborators became the first to measure the magnetic moment of the proton, as announced in the present paper (Stern's follow-up paper, written with Immanuel Esterman, was published in the *Zeitschrift* a few months later). Stern received the Nobel Prize for physics in 1943 for this achievement; his co-author, Otto Frisch, went on to play a crucial role in the discovery of nuclear fission.

Between 1923 and 1933, when Stern was professor of physical chemistry at Hamburg, he headed a program devoted to molecular-beam research. In the early 1930s he set out to test the validity of Dirac's theory that "the ratio of the magnetic moment of the proton to that of the electron should have been the same as the inverse ratio of their masses. This theory was believed so generally that when Stern, O. R. Frisch, and [Estermann] began the very difficult experiments, they were told more than once that they were wasting their time and effort. But Stern's perseverance paid off. Measurements showed a proton magnetic moment two or three times larger than expected . . . It is this work that was specifically mentioned in Stern's Nobel Prize citation" (*Dictionary of Scientific Biography*).

The proton's unexpectedly large magnetic moment remained a puzzle until the development of quark theory in the 1960s. It is now known that protons and neutrons are not elementary particles as once thought, but are composed of quarks, and the magnetic moments of the quarks can be used to compute the magnetic moments of the proton and neutron. Ezhela et al., *Particle Physics: One Hundred Years of Discoveries,* p. 69. 50962

**218. Szilard, Leo** (1898-1964) and **Thomas A. Chalmers.** Detection of neutrons liberated from beryllium by gamma rays: A new technique for inducing radioactivity. Offprint from *Nature* 134 (1934). Single sheet, unbound. [2]pp. 216 x 134 mm. Crease in upper left corner, lower right corner chipped, light toning but very good. *Presentation Copy,* inscribed in the upper right corner in an unidentified hand: "With compliments of L. Szilard." $2750


With compliments of L. Szilard

(*Reprinted from* NATURE, *Vol.* 134, *page* 494, *September* 29, 1934.)

DETECTION OF NEUTRONS LIBERATED FROM BERYLLIUM BY GAMMA RAYS: A NEW TECHNIQUE FOR INDUCING RADIOACTIVITY

BY

DR. LEO SZILARD

AND

T. A. CHALMERS

Physics Department, Medical College, St. Bartholomew's Hospital, London, E.C.1.

WE have observed that a radiation emitted from beryllium under the influence of radium gamma rays excites induced radioactivity in iodine, and we conclude that neutrons are liberated from beryllium by gamma rays.

Chadwick and Goldhaber were the first to observe a nuclear disintegration due to the action of gamma rays. In their pioneer experiment[1], they used a small ionisation chamber filled with heavy hydrogen and observed that protons were ejected from the heavy hydrogen under the influence of gamma rays from thorium C. Their method can be used for the detection of the gamma ray disintegrations of other elements, as such a disintegration would generally be accompanied by the ejection of *charged nuclei* which their method is designed to detect. On the other hand, apart from the unique case of heavy hydrogen, their method does not appear to give direct evidence on *neutron* radiations, which may in certain cases accompany gamma ray disintegrations.

It appeared to us of interest to search for such neutron radiations, and we thought that the Fermi effect might conveniently be used as an indicator of their presence. For certain reasons, we chose to use as indicators elements which, like iodine, are transmuted in the Fermi effect into their own radioactive isotopes.

In order to make our test more sensitive, we applied in this work the new principle of isotopic separation which we recently described[2]. In the present experiment we have used iodine as indicator, and separated radio-iodine from the bombarded iodine.

In one experiment we surrounded 150 mgm. of radium (in sealed containers of 1·0 mm. platinum filtration) with 25 gm. of beryllium, which was further surrounded by 100 c.c. ethyl iodide. The

**First Edition, Offprint Issue.** In 1933, after fleeing from Germany to England to escape the Nazis, Hungarian theoretical physicist Leo Szilard came up with the idea of the nuclear chain reaction while crossing a street in London. He filed his first patent on the chain reaction in March 12, 1934 and that summer, in collaboration with T. A. Chalmers, he began a series of experiments on the beryllium nucleus using radium owned by the physics department at St. Bartholomew's Hospital Medical College.

> The beryllium nucleus was so lightly bound [Szilard] suspected he could knock neutrons out of it not only with alpha particles or neutrons but even with gamma rays or high-energy X rays . . . Their first experiment demonstrated a brilliantly simple method for separating isotopes of iodine by bombarding an iodine compound with neutrons. They then used this Szilard-Chalmers effect (as it came to be called), which was extremely sensitive, as a tool for measuring the production of neutrons in their second experiment: knocking neutrons out of beryllium using the gamma radiation from radium (Rhodes, *The Making of the Atomic Bomb*, p. 215).

The results of this second experiment are described in the present offprint. To Szilard's disappointment, beryllium proved to be an unsuitable candidate for chain reaction; it was not until 1939, after the discovery of nuclear fission, that Szilard and Enrico Fermi were able to produce a nuclear chain reaction in uranium. The first self-sustaining nuclear chain reaction—which made possible the atomic bomb—was accomplished by Fermi and his associates in 1942. 43260

**219. Uhlenbeck, George E.** (1900-1988) and **Erich Beth.** The quantum theory of the non-ideal gas I. Deviations from the classical theory. Offprint from *Physica* 3 (1936). 729-745pp. 244 x 160 mm. Original printed wrappers, a bit sunned. Very good. Sheet with calculations and comments in Dutch laid in. $500

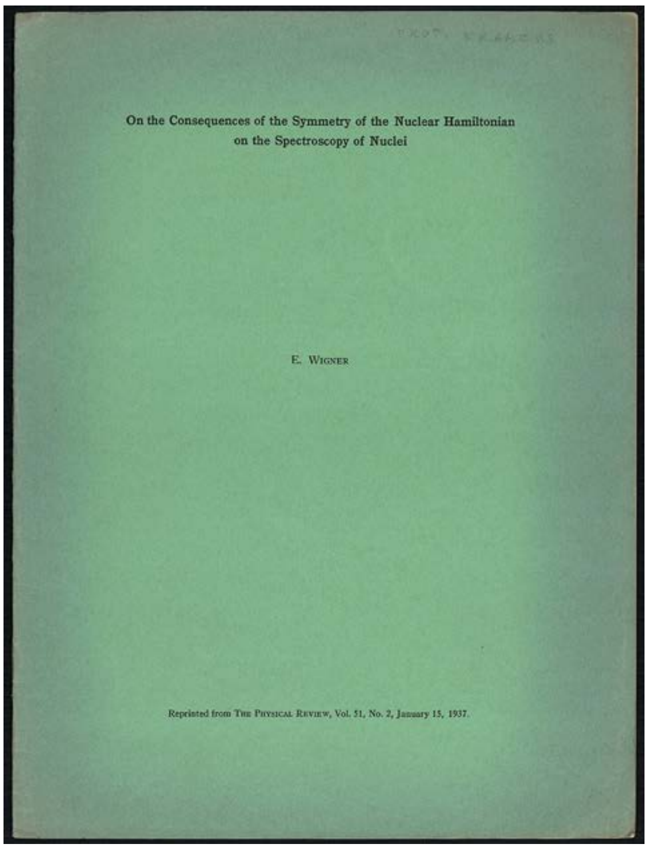
**First Edition, Offprint Issue.** Uhlenbeck is best known as the co-discoverer, with Samuel Goudsmit, of electron spin. 51012

**220. Wigner, Eugene** (1902-95). Über die Operation der Zeitumkehr in der Quantenmechanik. Offprint from *Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen, math.-phys. Klasse* (1932). 546-559pp. 245 x 171 mm. Original printed wrappers, detached, chipped, marginal tears. Fair to good copy. From the library of H. A. Kramers (1894-1953), with his name in pencil on the front wrapper. $500

**First Edition, Offprint Issue.** From the library of H. A. Kramers, one of the major architects of quantum theory. 51018

## *Independent-Particle Model of Nuclear Structure—Wigner's Nobel Prize-Winning Work*

**221. Wigner, Eugene** (1902-95). On the consequences of the symmetry of the nuclear Hamiltonian on the spectroscopy of nuclei. Offprint from *Physical Review* 51 (1937). 107-119pp. 267 x 200 mm. Original printed wrappers, slightly darkened at margins. Very good. H. A. Kramers' copy, with his name in pencil in block letters on the front wrapper. $5000




**First Edition, Offprint Issue.** Wigner's paper contains the initial development of the independent-particle model (IPM) of nuclear structure, describing the atomic nucleus in terms of a face-centered cubic lattice; this led to the development of the nuclear shell model in the 1940s and 1950s. "In a paper concerning the 'Symmetry of the nuclear Hamiltonian,' [Wigner] proposed what was soon acknowledged to be the foundation of the independent-particle model—and indeed was awarded the Nobel Prize in Physics in 1963 specifically for that work . . . the independent-particle quantal description of nucleon states established by Wigner has been in use by nuclear theorists ever since" (N. Cook, *Models of the Atomic Nucleus* [2nd ed.], pp. 202-203). Page 112 of Wigner's paper contains the first illustration of the lattice geometry of the nucleus. This copy is from the library of Dutch physicist H. A. Kramers (1894-1952), one of the major contributors to quantum theory. 46054

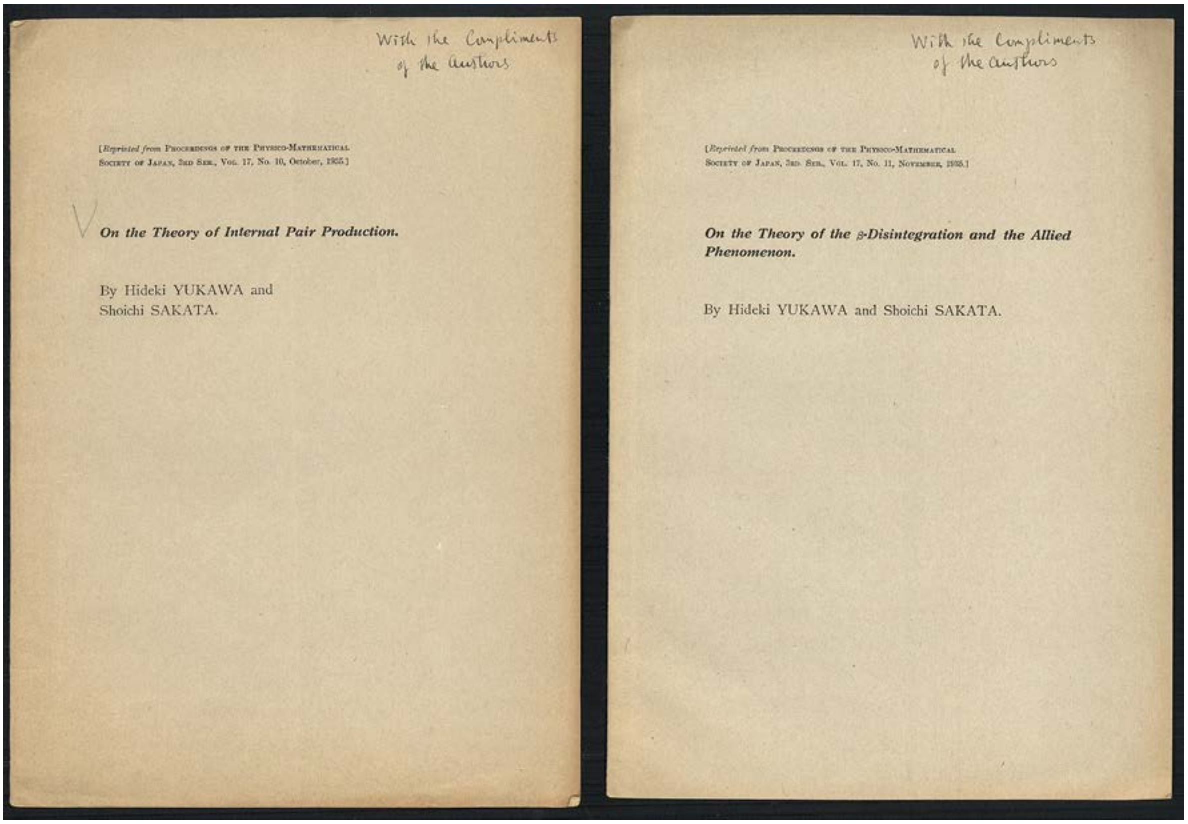
## *"The Physicist's Conception of Nature"—Archive Including 44 Signed Letters from Wigner*

**222. Wigner, Eugene** (1902-95). Archive of correspondence between Wigner and historian of physics Jagdish Mehra (1931-2008). 75 letters and other pieces, comprising ca. 135 pages. Oct. 14, 1969 – Aug. 31, 1989. Archive includes original autograph and typed letters signed, carbon typescripts and a few photocopies. Very good. Complete calendar of archive available here. $7500

A large group of correspondence between Nobel laureate Eugene Wigner, who received a share of the 1963 Nobel Prize in physics for his discovery and application of fundamental principles of symmetry to the theory of atomic nuclei particles, and historian of physics Jagdish Mehra, editor of Wigner's *Philosophical Reflections and Syntheses* (1995) and *The Collected Works of Eugene Paul Wigner* (1993), and author of *The Historical Development of Quantum Theory* (1982-2002) and many other works. The correspondence includes 44 typed or autograph letters / notes signed from Wigner to Mehra, plus carbons of Mehra's responses, a few of Mehra's drafts of letters to Wigner, and related material. The letters deal primarily with the organization of scientific conferences; several are devoted to the symposium "The Physicist's Conception of Nature," held in Trieste in 1972 in honor of Paul Dirac's 70th birthday, which Mehra organized and Wigner co-chaired. Other letters touch on Wigner's retirement in 1971 and Mehra's proposal to edit Wigner's collected papers. Also included in the archive is an undated autograph document in Wigner's hand, headed "Classical expression for Helmholtz function."

The Hungarian-born Wigner was a key player in the development of quantum and nuclear physics. He introduced the idea of parity as a conserved property of nuclear reactions (1927); developed (with his friend John von Neumann) the theory of energy levels in atoms on the basis of group theory (1928-32); devised the

"Wigner function" of momenta and coordinates (1932), which has become a major tool in the study of quantum chaos; provided (with his student Frederick Seitz) a basis for solid state physics in their method of treating electron wave functions in a solid (1933); and worked out with Gregory Breit the "Breit-Wigner" formula (1936) explaining neutron absorption by a compound nucleus. He also played an important role in the United States' development of the atomic bomb and nuclear reactors, working on the Manhattan Project during World War II and serving as director of the AEC Laboratory at Oak Ridge in 1946-47. 43473




## *First Japanese Physicist to Win the Nobel Prize in Physics*

**223. Yukawa, Hideki** (1907-81). (1) [with Shoichi Sakata] On the theory of the β-disintegration and the allied phenomenon. Offprint from *Proceedings of the Physico-Mathematical Society of Japan*, 3rd series, 17 (1935). 467-479pp. Original printed wrappers. *Presentation Copy,* inscribed "With the compliments of the authors" on the front wrapper. (2) [with Sakata] On the theory of internal pair production. Offprint from *Proceedings of the Physico-Mathematical Society of Japan*, 3rd series, 17 (1835). 397-407pp. Original printed wrappers. *Presentation Copy,* inscribed "With the compliments of the authors" on the front wrapper. (3) [with Sakata, Taketani and Minoru Kobayasi] On the interaction of elementary particles II [-IV]. Parts II and IV are offprints from *Proceedings of the Physico-Mathematical Society of Japan*, 3rd series, 19 (1937) and 20 (1938); Part III is a mimeograph typescript bound similarly to the other two offprints. 1084-93; 35; 720-745pp. Original printed wrappers. Together 3 items in 5 parts. 260 x 188 mm. Spine of no. (3), Part III split at extremities, light vertical creasing. Light browning, but very good. $4500

**First Editions, Offprint Issues**; **First Separate Edition (?)** of no. (3), Part III. In October 1934 Yukawa, then a lecturer in physics at Osaka Imperial University, proposed a unified theory of nuclear forces in which a set of hypothetical particles—now known as mesons—was responsible for the force binding positively charged protons and neutral neutrons together in atomic nuclei. The following year Yukawa published his paper "On the interaction of elementary particles" (not offered here), in which he set forth his meson theory, calculated the mass of the proposed particle (about 200 times that of the electron) and suggested that these particles might be present in cosmic rays. In 1936 Anderson and Neddermeyer reported anomalous cosmic-ray tracks made by particles intermediate in mass between the electron and proton; their observations were confirmed in early 1937 by several other cloud-chamber groups. In June 1937 Oppenheimer, Serber and Stueckelbert sent letters to the *Physical Review* calling attention to Yukawa's meson theory, and from then on its success, and that of its author, was assured. In 1949 Yukawa received the Nobel Prize for physics for his prediction of the existence of the meson.

Despite its later success Yukawa's meson theory attracted almost no attention in the two years following its announcement, largely because physicists were reluctant to accept the possibility of a new particle without direct observation confirmation. During this fallow period Yukawa published several joint papers with his student Shoichi Sakata on electromagnetic and nuclear phenomena. We are offering the first two of these joint papers in **rare offprint form** with even **rarer presentation inscriptions**. The paper on beta disintegration (no. [1] above]) is remarkable in that it contains the *only other published reference to the meson* prior to 1937. This paper includes "an important calculation of the inverse beta-decay process: the absorption of an orbital electron by a nucleus with the emission of a neutrino. [The paper] was noteworthy, not only because it was the first to call attention to a new effect but also because it was the *first additional application of the meson theory* [emphasis ours] and thus showed that Yukawa and Sakata had faith in it" (*Dictionary of Scientific Biography [Supplement]*).

In 1936, heartened by Anderson and Neddermeyer's discovery of a new unidentified particle in cosmic rays, Yukawa returned to meson theory. (It should be noted that Anderson and Neddermeyer's particle, although widely assumed at the time to be the one predicted by Yukawa, is in fact a decay product of the Yukawa particle; Yukawa's particle, now called the pi-meson or pion, was discovered by Powell and Occhialini in 1947.) In 1937 and 1938 Yukawa and his students published three more fundamental papers on meson theory (no. [3] above). "On the interaction of elementary particles II" presents a scalar meson theory of nuclear forces based on the Pauli-Weisskopf method, and speculates on the possible existence of an additional electrically neutral "heavy quantum." Part III introduces what is now called "vector meson theory"; the fourth and final part completes the pioneering work begun by Yukawa four years earlier.

Curiously, our copy of Part III is a mimeograph typescript bound in wrappers similar to those of Parts II and IV but omitting the journal imprint information (this information is supplied in manuscript below the wrapper title in our copy). The typescript has a mimeograph label inside the back wrapper with the undated imprint of Teidai Print in Tokyo. OCLC does not list any copies of the separate edition of Part III; we do not know if a typeset offprint version also exists. Magill, ed., *The Nobel Prize Winners: Physics*, pp. 561-69. Mehra & Rechenberg, *The Historical Development of Quantum Theory,* 6, pp. 831-836; 946-958. *Twentieth Century Physics,* 1, pp. 378-392. Weber, *Pioneers of Science,* pp. 133-34. 43268