

# Albert Einstein in Leiden

**During World War I, this university town in neutral Holland was, for Einstein, a respite from the abhorrent chauvinism of German academia. Leiden was also the home of his father figure Hendrik Lorentz and of his dear and tragic friend Paul Ehrenfest.**

Dirk van Delft

**A**lbert Einstein liked coming to Leiden, the Dutch city particularly known for its venerable university. Vienna-born theoretical physicist Paul Ehrenfest, professor at Leiden University since 1912, was one of his closest friends.<sup>1</sup>

Last July Rowdy Boeyink, a history-of-science student, stumbled across a long-lost, handwritten Einstein manuscript in the Ehrenfest Library of Leiden University's Lorentz Institute for Theoretical Physics. The manuscript was part two of a paper entitled "Quantum Theory of Monatomic Ideal Gases," which Einstein presented at a 1925 meeting of the Prussian Academy of Sciences.<sup>2</sup>

That paper has a special significance. It contained Einstein's last great discovery—Bose–Einstein condensation, as the effect came to be called. Unearthed amid the celebrations of the Word Year of Physics, the centenary of Einstein's 1905 *annus mirabilis*, the 16 handwritten pages attracted international media attention.<sup>3</sup> That same month, Boeyink also found among Ehrenfest's papers typescripts of two more Einstein papers—one from 1914, the other from 1920. Both manuscripts contain interesting differences from the version that eventually appeared in print (see box 1 on page 59).

Last October I came across reprints of 22 articles by Einstein from the period 1902–15 in the archive of the Huygens Laboratory, home to experimental physics at the university. In some cases, including the famous 1905 article on the special theory of relativity, the reprints feature handwritten "improvements" by Einstein himself (see box 2 on page 60).

## Einstein and Ehrenfest

How did the Einstein manuscripts and the hand-annotated reprints end up in Ehrenfest's library? They reflect the intimate bond between Einstein and Ehrenfest. How did that bond develop? What was Einstein's connection with Leiden and with two other leading scientists at the university, astronomer Willem de Sitter and Heike Kamerlingh Onnes, the discoverer of superconductivity?

In 1912 Ehrenfest succeeded Hendrik Antoon Lorentz (1853–1928) as professor of theoretical physics at Leiden.<sup>4</sup> Lorentz would have preferred to get Einstein, but Einstein

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opted for Zürich. Ehrenfest, who got his PhD in Vienna under Ludwig Boltzmann, had been working at the University of St. Petersburg in Russia since 1907. In Leiden, the Ehrenfests moved into a Russian-style villa designed by Ehrenfest's Russian wife Tatiana Afanashewa, a mathematician. They brought with them from St. Petersburg the tradition of a weekly colloquium, with frank and open discussion of the latest developments in physics. At first the colloquia met at the Ehrenfest home, but later they were held at the institute for theoretical physics.

The formal Lorentz would keep silent until he had his thoughts in order, but the high-spirited Ehrenfest viewed boisterous debate as absolutely essential. He was informal with students, his lectures and presentations were lively and lucid, and his German was peppered with colorful expressions like *Das ist wo der Frosch ins Wasser springt* (that's where the frog jumps into the water).

According to his student Hendrik Casimir, Ehrenfest was "a passionate admirer of the beautiful and the profound."<sup>5</sup> Yet he was increasingly weighed down over the years by doubts about his ability to keep pace with developments in the new physics, particularly quantum physics. Those doubts contributed to the deep depression that tragically led him to take his own life in 1933, at age 53. Boltzmann, his great teacher, had set him a sad example by committing suicide in 1906.

Nonetheless, Einstein and Ehrenfest were soul mates. They first met in February 1912 in Prague, where Einstein was a professor until he moved to Zürich later that year. The friendship clicked from the very beginning. They interrupted their intense discussions on subjects like the ergodic principle or gravitation to play Brahms sonatas, with Einstein on the violin and Ehrenfest at the piano (see the cover of this issue).

After spending a week at Einstein's home, Ehrenfest confided to his diary that he "was terribly happy. . . . Yes, we will be friends." The affection was mutual. In a 1934 eulogy Einstein wrote: "Within a few hours we were true friends—as though our dreams and aspirations were meant for each other."

Einstein first visited Leiden in February 1911. He had accepted a student invitation to give a lecture there because he was keen to meet Lorentz, a father figure whose work he valued highly. He also wanted to meet Kamerlingh Onnes and see his celebrated cryogenics laboratory. Interestingly, Kamerlingh Onnes had failed to respond to a 1901 letter from Einstein applying for a graduate assistantship. Einstein, who had just graduated from the Zürich Polytechnic, enclosed a stamped, self-addressed postcard and his recently published paper on intermolecular forces. The postcard disappeared into a folder in Onnes's home.

By 1910, Einstein was no longer an obscure supplicant. The research reports on critical opalescence that Kamerlingh Onnes sent to Prague that year with an eye

**Albert Einstein**, painted in 1920 by Harm Kamerlingh Onnes, nephew of the discoverer of superconductivity.

to Einstein's arrival were of common interest to both men. They elicited from Einstein a consignment of reprints of his own work.

Einstein and his wife Mileva stayed with Lorentz during that week in February 1911. Back home again in Prague, Einstein wrote to say how much he had enjoyed the hospitality and the scientific discussions. He expressed great interest in Onnes's research into the temperature dependence of the electrical resistance of metals. At the time, Kamerlingh Onnes was on the brink of observing superconductivity in mercury, a discovery he would present at the first Solvay conference in Brussels in the autumn of 1911. Einstein was a participant in that historic meeting.

During the next 20 years Einstein visited Leiden often. He enjoyed the scientific give and take. In Berlin, where he was based from 1914 to 1932, the theoretical physicists were generally unreceptive to wide-ranging discussions about fundamentals. But in Leiden he could talk in a relaxed fashion with Ehrenfest about his work on general relativity. In March 1914, shortly before his move to Berlin, Einstein spent a week at Ehrenfest's home. The two friends spoke at length about problems with quantum theory and statistical mechanics. Afterwards, Ehrenfest received a warm letter from Berlin in which, as a sign of close friendship, Einstein no longer addressed him with the formal *Sie* but rather with *du*.

### A neutral respite

After World War I began with the German invasion of Luxembourg and Belgium in August 1914, Einstein gratefully seized upon an invitation from Ehrenfest to visit the neutral Netherlands. Einstein abhorred the wave of nationalism that was sweeping the German academic community. As one of the few prominent academics who refused to sign the "Manifesto to the Civilized World," a pompous justification of the invasions that invoked Beethoven and Goethe, Einstein was desperate for a respite from all the patriotic hysteria. "Every fiber of my being itches to get away from here," he wrote his friend.

But traveling in wartime was not easy; it was many months before Einstein could arrange the necessary documents. He finally arrived in Leiden in September 1916 for a two-week visit. In Haarlem, he and Ehrenfest looked up the semi-retired Lorentz, with whom he had been corresponding intensively about general relativity, which had been published in its completed form the previous November. Back again in Berlin, Einstein wrote to his old friend Michele Besso that he had "spent unforgettable hours with Ehrenfest and especially with Lorentz, not only stimulating but also refreshing. I feel in general that I am



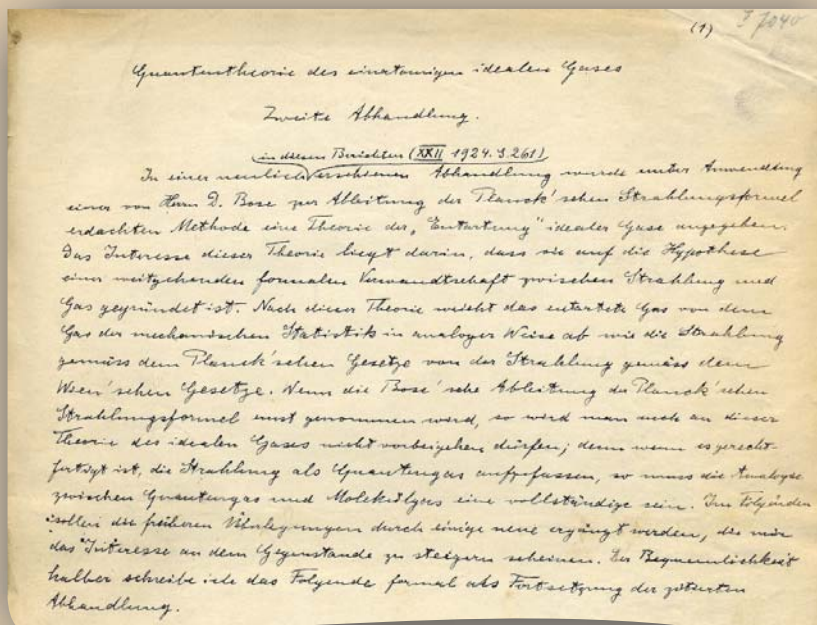
incomparably closer to these people [than I was before]." During his stay at Ehrenfest's home, Einstein had opened his host's eyes to the music of Bach. For several months thereafter, Ehrenfest seemed to be more taken up with choral music than with physics.

Because there was no free exchange of scientific ideas in wartime Europe, it was the Dutchman de Sitter who passed on the new general theory of relativity to England. At Arthur Eddington's request, de Sitter wrote a three-part paper entitled "On Einstein's Theory of Gravitation, and Its Astronomical Consequences" for the *Monthly Notices of the Royal Astronomical Society*.

Einstein first met de Sitter during his 1916 Leiden visit. The two spoke at length about general relativity and the residual elements of absolute space and time that it still preserved.<sup>6</sup> There ensued a detailed correspondence about cosmological solutions of the theory's field equations. That was the beginning of relativistic cosmology. Responding to Einstein's closed, static universe and its cosmological constant, de Sitter in March 1917 introduced his eponymous empty-universe solution.

Eddington, who was "immensely interested" in the new ideas, led the expedition that observed the deflection of starlight passing by the Sun during the solar eclipse of May 1919, thus confirming an important prediction of general relativity. Einstein learned of the happy news from Lorentz in September. With the official announcement of the Eddington expedition's result on 6 November 1919, Einstein became a superstar.





**Long-lost manuscript** of Einstein's 1925 paper "Quantum Theory of Monatomic Ideal Gases," which predicts Bose–Einstein condensation. The manuscript, which Einstein left in Leiden with Paul Ehrenfest, was recently rediscovered in the archives of Leiden University's Lorentz Institute.

Einstein could determine his own salary ("Our *maximum* of 7500 guilders [per annum] is your *minimum*"); he did not have to deliver lectures; and he could have unlimited travel. Ehrenfest stressed that Kamerlingh Onnes warmly supported the offer. "Please remember that you would be surrounded here by people who are fond of you personally, and not just of the stream of ideas that flow from you." Everything was possible, so long as Ehrenfest and company could say that Einstein was now at Leiden.

But Einstein declined the offer. It was certainly attractive, and he loved Leiden, but he couldn't simply follow his heart. Max Planck had pleaded with him to stay in Berlin. Overcome by the wretched state of the postwar capital city, Einstein opted for loyalty. He did, however, yearn to look up his Leiden friends once more. In the second half of October, he stayed with Ehrenfest. Back in Berlin, three days after the front page of the London *Times*

At the time, Ehrenfest, Lorentz, and Kamerlingh Onnes were busy trying to bring Einstein to Leiden as a guest professor.<sup>7</sup> They also tried to lure him to accept a full professorship. "The matter is very simple," Ehrenfest wrote to him on 2 September after consulting with his colleagues. "If you just say yes, we can . . . arrange everything extremely quickly in accordance with your wishes." Ehrenfest held out the prospect of an ideal existence in Leiden:

reported the verification of general relativity, Einstein wrote him a moving letter. "It feels as though you are a part of me, and that I belong to you. From now on we will stay in close personal contact with each other. That will do us both good—each of us feels less out of place in this world because of the other."

When it was clear that Einstein would not accept a full professorship, Leiden switched to plan B—the guest

### Box 1. Typescripts and Manuscripts

On his visits to Leiden, Albert Einstein left three documents with Paul Ehrenfest. They eventually disappeared between the pages of journals in Ehrenfest's study. When Ehrenfest's daughter Tanja died in 1984, his books and papers were left to the university's Lorentz Institute. And there the piles of paper stayed, undisturbed for decades until Rowdy Boeyink, working on his master's thesis, began leafing through them one by one.<sup>14</sup>

On his first visit to Ehrenfest in March 1914, Einstein left behind a typescript of his last Zürich paper. Entitled "Covariance Properties of the Field Equations of Gravitation Theory Based on the Generalized Theory of Relativity," it was to appear in May in the *Zeitschrift für Mathematik und Physik*. Coauthored with mathematician Marcel Grossmann, it was a follow-up to a paper they had written the previous year.

The 13-page typescript, with neat formulae handwritten by Grossmann, contains some corrections made by Einstein and a supplement—all of which were incorporated in the published version. The typescript also features comments and drawings in Ehrenfest's hand that bear witness to the intensive discussions in which the two friends grappled with ideas that would result, in November 1915, in the completed theory.

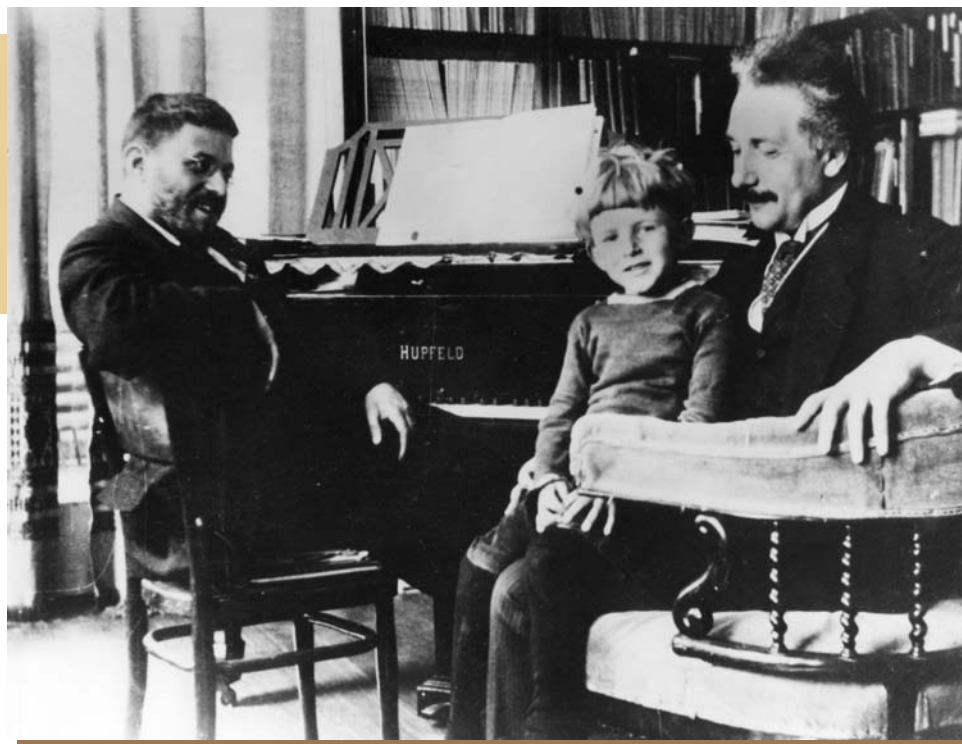
When Einstein visited Leiden in May 1920, he once again left behind a typescript. This time it was the page proofs of the paper "Propagation of Sound in Partly Dissociated Gases," which the Prussian Academy had published in April.

Thanks to his recently acquired stardom, Einstein received many requests and suggestions for what he termed "scientific diversions." One of those diversions involved researching the question of whether the speed of sound is frequency-dependent. The resulting article on gases didn't attract much attention. Nevertheless, it tied in with the experiments program at Walther Nernst's laboratory, and at Einstein's suggestion the national metrology institute in Berlin investigated the frequency-dependence of the speed of sound from 1920 to 1922. The results showed that there was no such dependence.

In the page proofs he left with Ehrenfest, Einstein had crossed out the last two pages and replaced them with a new handwritten conclusion. In the original version, he had applied a simplification to a complicated equation for the speed of sound. It applied to the special case of temperature much below the gas's decomposition heat per mole. In his derivation of the propagation speed for that simplified case, Einstein had made a few careless errors. The new version contains a more general result, not restricted to the low-temperature regime. That's the version that got published. But, here too, Einstein made several sign mistakes.<sup>15</sup>

Finally, on his penultimate visit to Leiden in February 1925, Einstein left behind his handwritten manuscript predicting Bose–Einstein condensation. It differs only in minor respects from the version ultimately published.

**Paul Ehrenfest and Einstein** at Ehrenfest's home around 1920 with elder son Paul Jr, who became a physicist. His institutionalized younger brother Vassily was shot by Ehrenfest in 1933, just before the tormented father took his own life. (Courtesy of AIP Emilio Segrè Visual Archives.)



WILLEM LUYTEN

professorship. On 9 November 1919, Kamerlingh Onnes, a shrewd organizer who was much better than Ehrenfest at getting his way with the authorities, approached the foundation that funded special chairs at the university. Who, he asked rhetorically, could lay greater claim to a special chair than Einstein, a “star of the first magnitude,” a man who could be “compared to Newton”? Onnes’s timing was perfect. Just days earlier Einstein had rocketed

to international fame. “A few weeks ago we had the great Swiss Einstein in our midst,” Onnes began. (A year after the armistice of 11 November 1918, the word “Swiss” was no idle addition, even in neutral Holland.) Onnes shrewdly added that “Einstein was led to his discoveries by building on Lorentz’s work in Leiden.” He suggested appointing Einstein for three years at a visitor’s salary of 2000 guilders per annum, and the foundation accepted.

Ehrenfest informed Einstein of the offer on 24 November. It would involve being in Leiden for three or four weeks a year. That appealed to Einstein; he described it as a “comet-like existence.” To the funding foundation, Onnes had further accentuated Einstein’s importance for Leiden by mentioning his own low-temperature work. The theory of relativity was of course of the greatest importance, he said, but “in other areas too, Einstein has produced work of great significance.” He pointed to Einstein’s contribu-

tions to quantum theory. “It was investigations at low temperatures that first shed light on many of the phenomena to which [quantum] theory relates.” For that reason, Onnes wrote, “Prof. Einstein attaches great importance to the work of the cryogenics laboratory,” and he emphasized his own eagerness to benefit from Einstein’s “teaching.”

In December 1919, Lorentz made the official offer to Einstein, emphasizing once again that Kamerlingh Onnes would be keen to discuss with Einstein matters arising from the cryogenics laboratory. Einstein accepted the offer and announced that his inaugural lecture—at Lorentz’s request—would be about “ether and the theory of relativity.” By “ether” Einstein meant, in this case, the gravitational field.

### “The Red Countess”

There was, however, a snag. Lorentz’s hope that the Dutch government would quickly confirm the appointment was

## Box 2. Einstein Reprints in Leiden

The reprints that Albert Einstein sent to Heike Kamerlingh Onnes found their way into the reprint archive of the Leiden Physics Laboratory. When physics moved to the outskirts of the city in 1998, most of the 30 000 items accumulated in the collection were discarded. But among the saved documents were 22 reprints of papers Einstein had written and sent to physicists at Leiden between 1902 and 1915.

Two of the papers contain prominent handwritten changes added by Einstein himself. One was the 1906 published version of his 1905 doctoral dissertation, “A New Determination of Molecular Dimensions.” In the margin of that paper, opposite a calculation on page 296, Einstein wrote the word “miscalculation.” He had sent the reprint to Kamerlingh Onnes in 1910, a few weeks before he discovered that particular error. So it may be that he asked Onnes, on his first visit to Leiden soon thereafter, if he could note the recently discovered mistake on the reprint.

The other hand-corrected reprint was the historic 1905 first paper on special relativity. Einstein made three changes, all in the introductory kinematic part of the paper. First, he expanded the title of section 1, “Definition of Simultaneity,”

to include “Principle of the Constancy of the Speed of Light.” Next he specified that the coordinate system introduced in the first sentence of that section be one “in which Newton’s mechanical laws hold, consisting of three fixed perpendicular bars.” And finally, he altered the somewhat woolly sentence, “Now we must bear carefully in mind that a mathematical description of [the motion of a material point] has no physical meaning unless we are quite clear as to what we understand by ‘time,’” to “Such a mathematical description is useful only if we have clarified what we mean by ‘time.’”

Why take the trouble to mark such purely pedagogic changes after the fact? In 1910 and 1911, Einstein published in *Annalen der Physik* supplements to articles that had already appeared. Language was important to him. In the words of his friend and biographer Abraham Pais, “His talent for the German language was second only to his gift for science.”<sup>16</sup>

Einstein often made changes to reprints of his paper on special relativity. But when in 1913 he prepared an amended version of the 1905 paper for a reprint volume of relativity articles written by him, Lorentz, and Hermann Minkowski, none of the hand corrections in the Leiden archive were incorporated.





**Einstein and Heike Kamerlingh Onnes**, drawn in 1920 by Kamerlingh Onnes's nephew Harm.

disappointed. Ehrenfest wrote Einstein in March that the royal decree was still “lying around in government departments,” but that an inaugural lecture on 5 May was surely possible. He took the trouble to acquaint Einstein with some of Leiden’s academic customs. Wearing the obligatory academic gown during the inaugural lecture made “speaking with one’s hands” impossible. And after the talk, before the host’s speech of thanks, Ehrenfest suggested, Einstein would do well to take his time drinking a glass of water so that the older gentlemen in the room could be shaken from their slumbers.

In fact, Einstein did not present his inaugural lecture until 27 October 1920. Why the long delay? It seems to have been a case of mistaken identity. The authorities in The Hague thought they were dealing with Carl Einstein, the German writer, art historian, and leftist revolutionary. That other Einstein, according to the committee that was to advise the minister of internal affairs on the appointment, was in Brussels, allegedly living in sin with the “Red Countess” Ada von Hagen, a well-known propagandist of the time. The shocked minister demanded a full explanation from the foundation.

“Prof. Einstein does not go in for countesses,” replied Professor Cornelis van Vollenhoven to the minister in a letter recently discovered by science historian Jeroen van Dongen.<sup>8</sup> “He has never lived at the address you mention. He is married to a Jewish woman whose maiden name is also Einstein. He did not live or stay in Brussels during the war.”

Although van Vollenhoven’s letter seemed to convince the minister, the royal decree was not enacted until 21 September. Meanwhile, at a meeting of the Society of German Natural Scientists in Berlin’s Philharmonic Hall, Einstein was branded a “publicity-seeking dog,” a “plagiarist,” a “charlatan,” and a “scientific Dadaist.” Einstein, never shy, attended the meeting—reportedly with occasional amusement—and hit back hard with a response in the *Berliner Tageblatt*.<sup>9</sup> As soon as Ehrenfest heard of the commotion in Berlin, he once again offered Einstein—on his own au-

thority—a full professorship, but Einstein stuck to the guest arrangement.

Kamerlingh Onnes seized the opportunity of Einstein’s debut as guest professor to organize a mini-conference on magnetism for October 1920. The only experimental work of Einstein’s scientific career, conducted in 1915 with Lorentz’s son-in-law Wander De Haas, had been on magnetism (see *PHYSICS TODAY*, April 2005, page 88). In addition to Onnes and Einstein, the other conference participants were Ehrenfest, Lorentz, Johannes Kuenen, Paul Langevin, and Pierre Weiss. The experimenter Weiss, who had just transferred from Zürich to what was now, once again, French Strasbourg, had in the past brought his heavy magnet with him from Zürich to conduct low-temperature magnetic investigations with Onnes’s group.

Since 1914, however, magnetic research at Leiden had fallen into something of a decline, and Onnes was seeking to revive it.

In 1920 Ehrenfest, who had been working primarily on paramagnetics during the war, began to devote himself to paramagnetism. So he was looking forward to the mini-conference. “I’m dying to discuss these matters,” he wrote to Einstein, who in turn regarded paramagnetism as “fully ripe for theoretical attention.” After the mini-conference, Onnes wrote a report on it for the 1921 Solvay conference. Ehrenfest summarized his thoughts in a paper on the paramagnetism of solid substances.<sup>10</sup> Einstein had his hands full with general relativity.

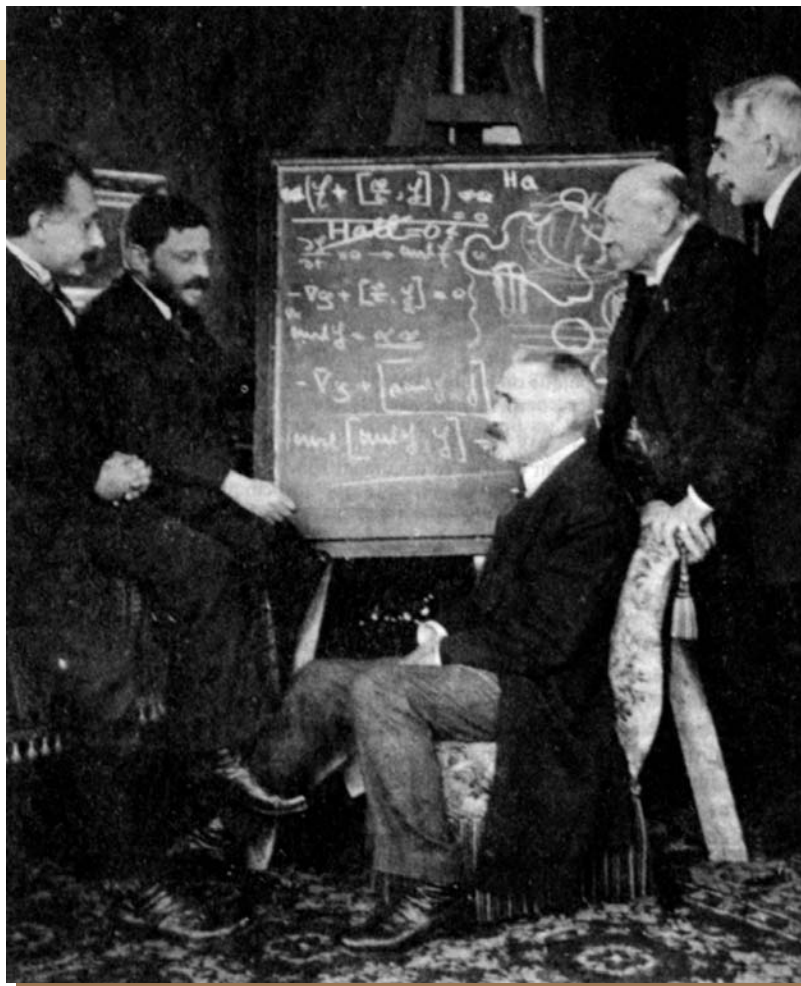
### Superconductivity

Einstein did, however, lecture on superconductivity at Leiden in November 1921. This time he was invited to stay at Kamerlingh Onnes’s home. The host was curious about Einstein’s views on quantum effects in superconductors. Einstein returned to that topic in 1924, giving Onnes several formulae based on speculative arguments of uncertain significance that one would have to test in the laboratory. Onnes replied that although he still had some reservations, Einstein’s suggestions had brought him “immense joy” and that the idea that quantum rules help determine the time that molecules spend in close proximity had been a “lightning flash” for him. But those notions remained vague. He was sure, he told Einstein, that they would lead to “something beautiful.” But at age 71, he was too old to do anything with them.

Kamerlingh Onnes was no Ehrenfest. Many years later Einstein recalled that scientific discussions with him were always rather awkward. There was nothing wrong with his intuition, said Einstein, but he could not find the right words to express himself and he was not very receptive to others’ lines of thinking.

In November 1922, Einstein set out his ideas on superconductivity in an article for the festschrift celebrating the 40th anniversary of Onnes’s professorship.<sup>11</sup> Following discussions with Ehrenfest, Einstein had arrived at a

At a 1920 conference on magnetism in Leiden are (left to right) Einstein, Ehrenfest, Paul Langevin, Heike Kamerlingh Onnes, and Pierre Weiss.



model of “chains of atomic electrons running almost in single file,” as he explained it in a postcard to his friend. In the superconducting state, he went on, these chains would be “stable and undisturbed.” Einstein suggested testing his theory by measuring the self-induction of a non-superconducting coil placed beneath a short-circuited superconducting coil. His festschrift article does not contain this somewhat vague suggestion, but he did stick to his electron-chain conjecture. However, after Kamerlingh Onnes found superconductivity across a lead–tin interface, Einstein did have to retract his hypothesis that the electron chains could not consist of different types of atoms.

Surprisingly, Einstein’s festschrift paper did not cite a contribution by Onnes to the 1921 Solvay conference.<sup>12</sup> In it, Onnes had also come up with the idea—in much greater detail than Einstein—of electrons moving via low “threads” from atom to atom. But Einstein had not attended the 1921 Solvay conference in Brussels, so he may not have known about Onnes’s contribution.

Over the years, Leiden benefited seven times from Einstein’s appearances as guest professor. In addition to typescripts and manuscripts, in 1921 he left his fountain pen behind as a gift at Ehrenfest’s home. Ehrenfest treasured it, noting that Einstein had used it to write all his articles and calculations on general relativity.

Einstein’s signature can be found in the visitors’ book at the Spinoza house in Rijnsburg, a village just outside Leiden. He made the visit in 1920 with Onnes’s nephew Harm Kamerlingh Onnes, a well-known painter. The 17th-century philosopher Baruch (Benedict) de Spinoza, whom Einstein greatly admired, had lived in that peasant’s cottage. There, when not writing, Spinoza ground lenses for a living. In a poem that Einstein, a prolific versifier, wrote that year, he said of Spinoza:<sup>13</sup>

*Wie lieb ich diesen edlen Mann,  
Mehr als ich in Worten sagen kann*

(How I love this noble man/ More than I can say in words.)

Einstein visited Leiden for the last time in April 1930. Shortly after he left Germany in December 1932 for a visit to the US, the Nazis came to power and Einstein never returned. The newly established Institute for Advanced Study in Princeton, New Jersey, was to be his scientific home for the remainder of his life.

On the afternoon of 25 September 1933, Einstein’s dear friend Ehrenfest picked up his younger son Vassily, who had Down syndrome, from the institution in Amsterdam that housed him. In a park nearby, the tormented man drew a revolver, shot the boy, and then killed himself.

*My thanks to Carlo Beenakker and Robert Visser for their valuable suggestions.*

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