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H. Johanna van Leeuwen, the Other Scientist behind the Bohr–Van Leeuwen Theorem

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2.1 Two Sisters in Leiden

In the early twentieth century, Hendrika Johanna ("Jo"; 1887–1974) and Cornelia ("Nel"; 1889–1974) van Leeuwen, two sisters from The Hague in the Netherlands, both travelled to Leiden to study physics. The two sisters were not the first women in the Netherlands to do so, but their choice was not so common either. Just like in other European countries, Dutch universities had only slowly begun to open their doors to women during the second half of the nineteenth century. The very first woman to complete any studies in a Dutch university was Aletta Jacobs, who subsequently obtained a doctorate in medicine at Groningen University in 1879. Her path had not been straightforward; she had to seek permission from the Dutch minister of education, Johan Thorbecke, and her case sparked extensive debates in newspapers of the time (Bosch, 2005). It is not surprising that women – following Jacobs' footsteps – only slowly trickled into the universities; by the end of the nineteenth century just about one in every 17 Dutch students was a woman (Kirejczyk, 1993).[1]

One of the hurdles on their path to higher education – as in most other European countries – was the lack of preparatory education. Traditionally, the so-called gymnasia prepared the sons of the Dutch elite to study law, medicine, or the humanities, and henceforth for a career in the judiciary, the government, or the military. In 1863, the same minister Thorbecke who would later grant Jacobs permission to study, established an alternative school type, the *Hogere Burger School* (Higher Civic

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[1] The total number of students in the Netherlands in 1900 was roughly 2,800 according to Statistics Netherlands (Centraal Bureau voor de Statistiek (CBS)), which began to register these numbers in 1900. CBS, "Leerlingen en studenten; onderwijssoort, vanaf 1900": https://www.cbs.nl/nl-nl/cijfers/detail/37220

School, or HBS for short), to modernize the educational system. The HBS aimed to prepare boys for careers in the rapidly expanding commerce and industry sectors. Being more affordable than the traditional gymnasia, it drew sons from families of lower socio economic status, who, along with the professors' and reverends' sons in their classrooms, shared an interest in the natural sciences. The HBS's emphasis on mathematics, physics, and chemistry soon also led to a new pathway to university: Talented boys with an HBS diploma who passed the state exams in Latin and Greek as well, could now pursue university studies, a privilege previously reserved for those with a gymnasium diploma (Boekholt and De Booy, 1987, pp. 179–190; Van Steen, 2003, pp. 89–93; Baneke and Maas, 2018).[2]

For girls, circumstances were different. The law did not formally forbid them from attending school. But while Thorbecke's 1863 law on higher education mandated that every town with over 10,000 inhabitants should establish an HBS for boys, the provision of schooling for girls was left at the discretion of local city councils. Even if an HBS for girls was established, its curriculum usually diverged from that of the "traditional" HBS. English, French, German, geography, history, and biology were taught in roughly the same manner, but math, physics, and chemistry were combined into a single "natural sciences" course. The hours freed as a result were instead devoted to courses in needle work, dietetics, health, and sometimes music (Van Steen, 2003, pp. 85–86 and pp. 100–102). Thus, for girls with an interest in the natural sciences, the only option was to enrol in an HBS for boys, but this option came with hurdles too: the minister of education had to grant them an exemption and the school had to permit girls to attend (Bosch, 1993).

Clearly, such a step also required parents or other family members who were receptive to the idea of an education that did not solely prepare girls for future roles as wives, mothers, and caregivers, *and* who were able and willing to finance such an education. Pieter van Leeuwen and Maria van Leeuwen-Schepman, both trained as elementary school teachers, were such parents. They must have been closely observing the developments in The Hague, for in 1901, as soon as one of the city's HBS schools for boys began admitting girls, they enrolled their daughters: Nel in the first grade and Jo, who had previously spent a year at another school, in the second. Later, they also allowed their daughters to take the state exam in Greek and Latin and subsequently to study physics in Leiden, with Jo starting in 1906[3] and Nel in 1907[4] (Kroon and Blok, 2021).

[2] A famous example of someone who took this route is Nobel laureate Hendrik Lorentz, the son of a horticulturist (Capponi and Frenken, 2021; Kox and Schatz, 2021).

[3] Jo spent this year at the *Hoogere Burgerschool met driejarigen cursus voor jongens* (Higher Civic School with a three-year course for boys), which offered a reduced HBS curriculum and was open to girls from 1899 on. Archief van de Dalton hbs, 1883–1963, Haags Gemeentearchief, Den Haag.

[4] In 1901 the city council of The Hague decided that the *Hoogere Burgerschool met vijfjarigen cursus* (Higher Civic School with a five-year course) could open its doors to girls. Thorbecke Scholengemeenschap, Haags

In this chapter, we discuss how circumstances, chance, societal expectations, and (internalized) gender stereotypes shaped the lives of the two sisters in vastly different fashion. We focus especially on the career as (quantum) physicist of the elder sister, Jo van Leeuwen.

2.2 Flourishing Physics in Leiden

In retrospect and given the limited number of primary sources about the Van Leeuwen sisters, we can only guess what it must have been like for them to take the train to Leiden and to walk to the red brick physics building – het Natuurkundig Laboratorium (Physics Laboratory) – that quietly faced one of Leiden's canals. Leiden University, founded in 1575, prided itself on being the oldest university of the Netherlands. In the seventeenth and eighteenth centuries, it had been the working place of scientists like physicist Pieter van Musschenbroek (1692–1761), co-inventor of the well-known Leyden jar, and famed physician and botanist Herman Boerhaave (1668–1738). Admittedly, during the first half of the nineteenth century, academic life in this city surrounded by low polders had become a bit sleepy and dull (Kox and Schatz, 2021, p. 77). But when the two sisters arrived in the early twentieth century, it was booming again, especially in the natural sciences, bringing forth several Nobel prizes in quick succession.

The steep rise in academic activity and recognition started about 10 years before the Van Leeuwen sisters began their studies, with the 1896 discovery of the splitting of spectral lines in a magnetic field by experimental physicist Pieter Zeeman. Theoretical physicist and Leiden professor Hendrik Lorentz would soon explain this unexpected "Zeeman effect" with his so-called electron theory, and in 1902 both men shared the Nobel Prize in Physics. Roughly a decade later, Heike Kamerlingh Onnes (1853–1926) would liquefy helium to study metals at extremely low temperatures, leading him to serendipitously discover superconductivity. He too would receive the Nobel Prize in Physics for his discovery, in 1913. The prestige of Leiden University was further boosted by two other Dutch Nobel laureates, Johannes van der Waals (Nobel Prize in Physics, 1910) and Jacobus van 't Hoff (Nobel Prize in Chemistry, 1901), who had studied there.

Historians of science often attribute the "mild rain" of Nobel prizes to the introduction of the HBS (Baneke and Maas, 2018; Kox and Schatz, 2021, pp. 84–86). It was even more remarkable given that around 1900 the combined physics departments of all Dutch universities employed only 18 staff members, six of whom (Lorentz, Kamerlingh Onnes and four assistants) worked in Leiden (Kox and Schatz, 2021, p. 78). As a result,

Gemeentearchief, Den Haag. Until 1906, girls still had to obtain permission from the minister of education as well (Bosch, 1993).

from the onset of their studies, Leiden physics students were taught by the Nobel laureates themselves. Whether or not these lectures were inspiring is another question. As a former student, Dirk Jan Struik, later noted: “We had to attend once a week a lecture by Kamerlingh Onnes, who hated to leave his lab and demonstrated it by reading his notes in as dull a way as possible” (Van Delft, 2005, p. 336). By contrast, Lorentz’s lectures were often qualified as marvellous, flawless, and crystal clear, though perhaps even too smooth: “you could just copy it [the blackboard] and print it” (Gorter, 1962). Much later, Jo van Leeuwen would recall how much Lorentz meant to students outside of the lecture room as well (Van Leeuwen, 1925):

> It was not a coincidence that the first thing I was told by one of the elder students that guided me a bit after having arrived in Leiden, was this: “If we realize that one of us needs a bit of extra encouragement, we always ask if professor Lorentz wants to talk to him [sic] and he will then help him overcome his temporary discouragement.”[5]

Perhaps Jo and Nel may have felt that Lorentz was in favor of women attending the university. His own daughter Berta (full name: Geertruida Luberta) was among the first women to study physics in Leiden and would in 1912 obtain a PhD in physics under her father’s supervision. Around 1905, Lorentz had even supplied the newly founded Vereeniging van Vrouwelijke Studenten Leiden (Association of Female Students Leiden, VVSL) with feminist literature (Kox and Schatz, 2021, p. 49). This was in line with his long-running stance on women’s rights. Around the turn of the century he had, for example, accompanied his wife Aletta Lorentz-Kaiser to meetings of the Nederlandse Vereeniging voor Vrouwenkiesrecht (Dutch Association for Women’s Suffrage), established at the initiative of Jacobs. Later he had also taken part in meetings and dinners of its more moderate demerger, the Nederlandsche Bond voor Vrouwenkiesrecht (Dutch Union for Women’s Suffrage) in which Lorentz-Kaiser played a leading role. And even though Lorentz himself had always expressed his views with moderation – conforming to his character – these activities nevertheless made him more progressive than many of his colleagues, some of whom even called him a “feminist à outrance [extremist]” (Kox and Schatz, 2021, p. 45).

What Nel and Jo van Leeuwen thought of this, if anything, cannot be inferred from the scarce sources available. We do know that this early generation of women students struggled to find their place. Interestingly, many of them (up to 50%) opted for joining the faculty of *wis- en natuurwetenschappen* (mathematics and natural sciences), most choosing pharmacology as their specialty (Kirejczyk, 1993).

[5] Unless otherwise specified, all translations are from the authors. Original: “Toeval was het dus niet, dat onder het eerste wat mij verteld werd door een van de oudere studenten in de wis- en natuurkunde, die mij bij aankomst in Leiden wat wegwijs maakte, het volgende was, ‘Als we weten, dat er een van ons «en riem onder het hart gestoken moet worden, vragen we of professor Lorentz eens met hem praten wil en hij helpt hem over de tijdelijke ontmoediging in zijn studie heen’.”

Yearbooks of the associations of female students in Delft and Leiden reveal that they were afraid to be judged as overly serious, on the one hand, and too feminist, on the other. "Don't be a prudent little miss, nor a shrew with a 'do-not-come-near-me-attitude,' but especially avoid turning into a male-like person with offhand manners and coarse language," was the advice still given to new members of the Association of Female Students in Delft in 1930 for example.[6] In sum, the Van Leeuwen sisters, finding their way in the Leiden physics buildings where all lecturers and supporting staff were male and where few women had ventured into before, must have felt like pioneers exploring new possibilities for leading a woman's life.

2.3 A Graduate Student of Hendrik Lorentz

Did the two Van Leeuwen sisters support one another during their studies in Leiden? Did they perhaps share notes and ideas? Once more, the scarcity of sources makes it impossible to answer such questions. What we do know is that Nel, the younger of the two, began to work on a doctoral thesis under the supervision of Willem Keesom in 1916. In that same year, she and her supervisor wrote an article on the second virial coefficient of hard quadrupole molecules that appeared in the *Proceedings of the Royal Dutch Academy of Sciences* (Keesom and Van Leeuwen, 1916). However, Nel's research came to a halt after the summer of 1917, when she married the Finnish theoretical physicist Gunnar Nordström, an expert in the field of gravity who had been working in Leiden with Paul Ehrenfest for two years.[7] By autumn of 1918 Nel gave birth to a son,[8] and shortly afterwards she and her family moved to Finland where Nordström had been appointed a professor of physics at Helsinki University of Technology. Nel's path thus followed the conventions of traditional Dutch society which dictated that wives and mothers stayed at home, and she left the field of physics – although it remains unclear whether she did so with regret.

Her elder sister Jo would follow an altogether different path. In 1914, under the supervision of Lorentz, she began to investigate the microscopic origin of magnetic phenomena in solids from a classical-mechanical point of view. Lorentz, in his sixties and formally retired from the university since 1912, had by then even more prestige than shortly after receiving the Nobel Prize (which was not as glamorous

[6] Homans, L. N. S. (1930). Toespraak tot de nieuwe leden. In Almanak der Delftsche Vrouwelijke Studenten Vereniging. Delft: J. Waltman. https://erfgoed.tudelft.nl/en/objects/trt-784. Original: "Wees geen preutsch juffertje, geen kat met een raak-me-niet-aan-houding tegenover haar mede-studenten, maar vooral geen vermanlijkt wezen met onverschillige manieren en ruwe woorden."

[7] Marriage Certificate, August 14, 1917, 0335 – Huwelijksakten, Inventaris nr. 883, Haags Gemeentearchief, Den Haag. Note, Paul Ehrenfest was one of the witnesses.

[8] Birth Certificate, October 23, 1918, 0351 – Bevolkingsregister, Inventaris nr.1291, Haags Gemeentearchief, Den Haag.

then as it is today). His growing international standing was related to his role as chair of the famous Solvay Councils that allowed him to display both his theoretical physics knowledge as well as his language fluency (Berends, 2015). In the words of Einstein, written shortly after the very first such council in 1911 in Brussels: "H. A. Lorentz chaired the meeting with incomparable tact and unbelievable virtuosity. He speaks all three languages [English, French, and German] equally well and has a unique scientific acumen."[9]

Not only did he reap rewards from many decades of work and study, Lorentz also supervised four female graduate students between 1912 and 1919.[10] Other than his daughter Berta (see Section 2.2), who worked on the Brownian motion of electrons, thus making her one of the first scientists to look into the phenomenon of thermal noise (De Haas-Lorentz, 1912, p. 82),[11] they were Johanna Reudler, who worked on black-body radiation (Reudler, 1912); Eva Dina Bruins, who like Van Leeuwen studied topics from the field of magnetism (Bruins, 1918); and Van Leeuwen herself. Lorentz first mentioned her as one of his PhD students in a letter to his daughter Berta in early 1914, adding that she was still unsure about her dissertation topic.[12] Five years later, on January 20, 1919, Van Leeuwen received a doctorate for her thesis *Vraagstukken uit de electronentheorie van het magnetisme* (Problems from the electron theory of magnetism) (Van Leeuwen, 1919).

2.4 First Steps

When Van Leeuwen (see Figure 2.1) began her graduate work in 1914, quantum physics was still in its infancy. Not many years had passed since Max Planck, in 1900, had managed to properly describe the black-body radiation spectrum by introducing the fundamental constant, h, thus laying the foundation for the concept of energy quanta. And it was less than a year since Niels Bohr, in 1913, had incorporated this concept of energy quantization in his revolutionary model of the hydrogen atom, as well as in a model for the hydrogen molecule that Van Leeuwen would later build upon (Bohr, 1913a, b, c).

Building on the work of Planck and many others, Bohr's brand-new model described hydrogen atoms as consisting of a tiny, dense nucleus around which an electron revolved – the charged microscopic constituent of matter that according to Lorentz's electron theory was responsible for the interaction between light and matter.

[9] Einstein to Zangger, November 7, 1911: (Berends and Van Delft, 2021, p. 316).

[10] During his career Lorentz supervised 26 graduate students in total: https://www.lorentz.leidenuniv.nl/IL-publications/dissertations/lorentz.html

[11] This thermal noise is nowadays called Johnson–Nyquist noise after John Johnson, who first measured it at Bell Laboratories in 1926, and Harry Nyquist, who then was able to explain the results.

[12] Lorentz to De Haas-Lorentz, February 22, 1914, 364 – Prof. Dr. H. A. Lorentz Archive, Inventaris nr. 752-754, Noord-Hollands Archief, Haarlem.

Figure 2.1 Portrait photo of Jo van Leeuwen (date unknown, but surely before 1925). Image courtesy of the Van Leeuwen family.

Bohr realized that such an electron could only revolve without radiating (and thus losing) energy when moving in well-defined, stable orbits and he postulated that in such orbits the angular momentum of the electron was equal to an integer multiple of the Planck constant. In other words, he associated each orbit with a specific angular momentum and, consequently, with an energy level of the electron (and henceforth the atom). Finally, Bohr proposed that the electron could jump from one orbit (or energy level) to another by emitting or absorbing light of a specific frequency, and hence carrying a specific energy corresponding to the energy difference between the two levels (Bohr, 1913a, b). In one bold sweep his model thus illustrated how quantization was an intrinsic property of not only light but of matter as well, *and* that it played an essential role in the interaction between the two.[13]

[13] Bohr notably also built upon Ernest Rutherford's experimental results showing that the atom has a dense nucleus at its core, and on theoretical work especially by Einstein who could account for the photoelectric effect

Support for his groundbreaking idea came from calculations of the observed absorption and emission spectra of hydrogen that were made using Bohr's model of the atom (see Chapter 1). More specifically, the results of such calculations were in accordance with the empirically established Rydberg formula that recapitulated the emission spectrum of hydrogen. However, Van Leeuwen – during her first, explorative steps in research – left such calculations aside. Instead, she built on the third part of Bohr's 1913 trilogy on the structure of atoms and molecules, in which he proposed a model for the hydrogen molecule (Bohr, 1913c; for a further discussion of his trilogy, see: Kragh, 2012; Aaserud and Heilbron, 2013; Duncan and Janssen, 2019, pp.145–201).

Bohr described the hydrogen molecule as consisting of two nuclei with their two electrons revolving on a circular orbit, midway and perpendicular to the axis connecting the nuclei. Expanding on this work and refinements by Peter Debye (Debije), Van Leeuwen performed calculations to understand if oscillations might occur in such molecules in the absence of any external forces (Debije, 1915). By assuming, as Debye had done, that the nuclei themselves would to a good approximation stay in place, such "free oscillations" would consist of vibrations of the electron orbit expanding and shrinking at well-defined frequencies. Van Leeuwen then tried to ascertain if these vibrations could be triggered by the fluctuating electric field of light waves passing the hydrogen molecules, a bit comparable to triggering a tuning fork by hitting it on a surface (Van Leeuwen, 1916). In other words, she combined Bohr's quantum model of the molecule with the classical ideas about the interaction between light and matter from Lorentz's electron theory (see Section 2.5). She did not succeed, however.

Her work did nevertheless catch the attention of two young colleagues, who felt tempted to improve and expand upon it. The first was Jan Burgers, who would receive his doctorate from Ehrenfest in 1918 and who would subsequently become professor of fluid mechanics at the Technische Hoogeschool (Technical College) in Delft (TH Delft); the current Delft University of Technology. Much later he recalled: "Before I started to do anything myself, in 1916 Miss (van Leeuwen) [. . .] had worked out the free oscillations of the Debye model of the hydrogen molecule. She just assumed that the [electron] orbits were given there, and then calculated the free oscillations to see whether you could explain the absorption spectrum of hydrogen, and that she did not succeed in doing" (Burgers, 1962). For his own calculations Burgers decided to employ elements of Edmund T. Whittaker's *Analytical Dynamics*, which he had just been studying (Burgers,

on the assumption that light sometimes behaves as particles with quantized energies and, similarly, for the specific heats of solids at low temperature on the basis of a model of a solid consisting of harmonic oscillators with quantized energies (Duncan and Janssen, 2019, pp. 45–201).

1917). However, his work did not lead to significant improvements, as he later admitted: “I did not get much result either” (Burgers, 1962).

Something similar happened to Polish physicist Adalbert (Wojciech) Rubinowicz, who would become professor of theoretical physics at the University of Ljubljana in 1920. In 1917, while in Salzburg and having some time to spare, “I read a paper by Miss Van Leeuwen. And so, I thought it would perhaps be interesting to generalise the thing, to see how the nuclei move,” he later recalled (Rubinowicz, 1963). Once his calculations were published in *Physikalische Zeitschrift* (Rubinowicz, 1917), Rubinowicz sent an offprint to Van Leeuwen, who politely thanked “Dear Dr. Rubinowicz” for his “paper on the natural oscillations of the Bohr–Debije H_2 molecule.”[14] Yet, she also seemed to subtly suggest that his work merely confirmed hers: “[Y]ou have had to do a lot of calculating before you came to the insight that there are indeed no new unstable modes of vibration to add to the already known ones.”[15] Much later, Rubinowicz himself seemed to agree with that judgement when he described his own paper, laughingly, as “surely of no importance” (Rubinowicz, 1963).

2.5 Magnetism as a Quantum Phenomenon

The largest and by far most important part of Van Leeuwen’s doctoral work built on the centerpiece of Lorentz’s long career: his electron theory (*electronentheorie*). Her work would culminate in the demonstration that magnetism is an intrinsically quantum phenomenon, but to understand how this conclusion came about, we must first briefly describe Lorentz’s theory of the electron.

Beginning with his 1875 dissertation, Lorentz had built on Maxwell’s theory of electromagnetism[16] that so beautifully describes magnetic and electric phenomena, defines the relationships between electricity and magnetism, and shows that light consists of self-propagating, alternating, electric and magnetic waves, that is, electromagnetic waves. That theory, however, left open the details of the microscopic interactions between light and matter that underpinned macroscopic phenomena such as light reflecting from a surface, or the refraction of light that passes from one material to another.

By 1878, Lorentz had proposed that tiny, electrically charged constituents of matter were responsible for these interactions at the microscopic scale. He initially

[14] Van Leeuwen to Rubinowicz, June 26, 1917. Archive for the History of Quantum Physics, APS. Original: “Sehr geehrter Herr Dr. Rubinowicz, Für den mir zugeschickten Sonderdruck Ihrer Arbeit über die Eigenschwingungen des Bohr–Debijeschen H_2 Molekül danke ich bestens (. . .). Hochachtungsvoll, H. J. v. Leeuwen.”

[15] Original: “Sie haben eine grosze Rechenarbeit gehabt, bevor sie wussten dass sich in der Tat keine neuen instabilen Schwingungsweisen zu den alten fügten.”

[16] For his thesis work and in the first years thereafter he used Hermann von Helmholtz’ formulation of Maxwell’s theory (Kox and Schatz, 2021, pp. 56–65)

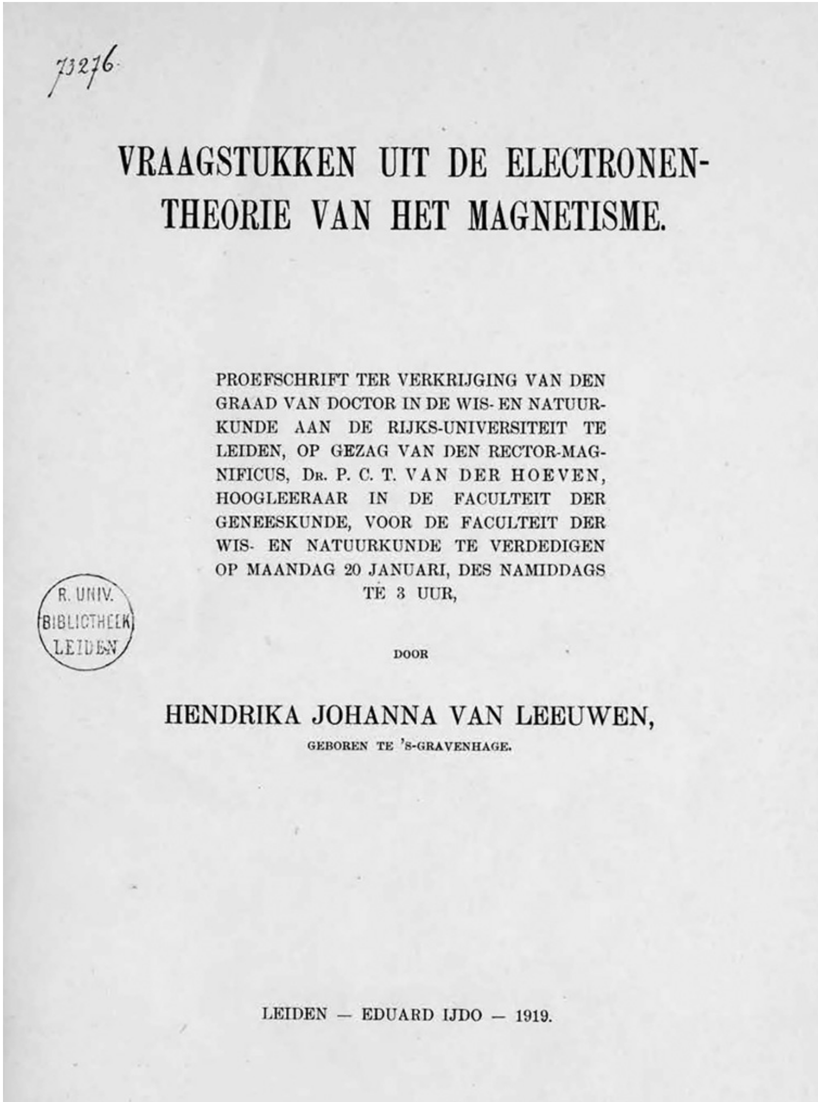
called these "ions," but by 1899 he had adopted the name "electrons."[17] Such charged particles would begin to oscillate when "hit" by a light wave and, since oscillation entails acceleration, the oscillating charged particles would consequently emit radiation themselves. Crucial to Lorentz's final electron theory was that it also helped translate electric and magnetic interactions on microscopic scales (where the electric and magnetic field strengths vary rapidly) to phenomena observed at a macroscopic scale by calculating average field values for groups of many atoms and molecules (Kox and Schatz, 2021, pp. 56–65). Because Maxwell's theory gives that an electric current (or, for Lorentz, a moving electron) induces a magnetic field, one could then try to predict if and how moving electrons inside matter (i.e., at the microscopic scale) would give rise to magnetism (at the macroscopic scale).

Building on Lorentz's classical-mechanical work, Van Leeuwen investigated a range of magnetic phenomena. The first chapters of her thesis (see Figure 2.2) explore whether and how specific types of magnetic behavior may arise in hypothetical gases consisting of neutral atoms and molecules that interact via elastic collisions. Van Leeuwen studies cases in which these molecules have an electric dipole moment (i.e., an asymmetric charge distribution causing the molecule to have a positive and a negative pole) or some other internal charge distributions and compares her results with earlier (semi-classical) work by French physicist Pierre Langevin (Langevin, 1905). She also examines the magnetic behavior of free electrons in metals, elaborating on two slightly different proofs that these do not produce a net magnetic moment given by Lorentz during a lecture in the academic year 1910–1911, and comparing and contrasting these results with earlier work by Waldemar Voigt, Erwin Schrödinger, and Joseph Thomson (Van Leeuwen, 1919).[18]

The most relevant aspect of Van Leeuwen's thesis from the perspective of quantum physics is her showing that any dynamical classical-mechanical system in a magnetic field in thermal equilibrium (i.e., with no net energy flowing into or out of the system) has no net magnetic dipole moment, and thus cannot give rise to

[17] Lorentz called these constituents ions at first but adopted the name "electrons" after the German physicist Emil Wiechert and the British physicist Joseph Thomson in their so-called "cathode-ray experiments" discovered these negatively charged particles outside atoms as well. The name "electron" had already been introduced in 1891 by the Irish physicist George Johnstone Stoney for hypothetical units of electrical charge (Kragh, 2023, pp. 75–76).

[18] Indeed, on page 66 of her thesis, Van Leeuwen refers to two lectures by Lorentz in which he suggested that the free electrons in a metal do not in fact give rise to a net magnetic moment. His argumentation was succinct and somewhat sketchy in Göttingen in 1913, where according to the proceedings he concluded "that one cannot attribute the diamagnetic properties of a metal to the curvature of the electron orbits caused by the magnetic field, as J.J. Thomson tried to do" ("Wie mir scheint, kann man hieraus schliessen, dass man nicht, wie J. J. Thomson versucht hat, die diamagnetische Eigenschaften eines Metalles auf die durch das Magnetfeld verursachte Krümmung der Elektronenbahnen zurückführen kann." See Lorentz (1914)). A more detailed proof was given in Lorentz's 1910–1911 "Capita Selecta" lecture series at the University of Leiden (see: 364 – Prof. Dr. H. A. Lorentz Archive, Inventaris nr. 265, pp. 47–51, Noord-Hollands Archief, Haarlem).



VRAAGSTUKKEN UIT DE ELECTRONEN-THEORIE VAN HET MAGNETISME.

PROEFSCHRIFT TER VERKRIJGING VAN DEN GRAAD VAN DOCTOR IN DE WIS- EN NATUURKUNDE AAN DE RIJKS-UNIVERSITEIT TE LEIDEN, OP GEZAG VAN DEN RECTOR-MAGNIFICUS, Dr. P. C. T. VAN DER HOEVEN, HOOGLEERAAR IN DE FACULTEIT DER GENEESKUNDE, VOOR DE FACULTEIT DER WIS- EN NATUURKUNDE TE VERDEDIGEN OP MAANDAG 20 JANUARI, DES NAMIDDAGS TE 3 UUR,

DOOR

HENDRIKA JOHANNA VAN LEEUWEN,

GEBOREN TE 'S-GRAVENHAGE.

LEIDEN — EDUARD IJDO — 1919.

Figure 2.2 Title page of the dissertation of Hendrika Johanna van Leeuwen.

magnetism. In other words, using statistical methods she proves that the thermal mean of the magnetization of such a system is identically zero and that the net magnetic susceptibility (i.e., the degree to which a material can be magnetized in an applied magnetic field) vanishes completely (Van Leeuwen, 1919, p. 34 and p. 49).

Her finding directly implies that classical-mechanical models cannot explain the origin of the various types of magnetism such as paramagnetism, diamagnetism, and ferromagnetism. Or, as the American physicist and Nobel laureate John Van Vleck (1899–1980) wrote in his seminal 1932 book on the topic (Van Vleck, 1932, pp. 94–95):

> [I]n 1919 Miss van Leeuwen demonstrated the remarkable and rather disconcerting fact that when classical Boltzmann statistics are applied completely to any dynamical system, the [magnetic] susceptibility is zero. We shall refer to these results as "Miss van Leeuwen's theorem".[19]

However, whereas Van Leeuwen's work might be viewed as "disconcerting" from a classical-mechanical perspective, it could also be interpreted quite positively from a quantum perspective: magnetism must be a quantum property. Van Leeuwen herself, who seemed as moderately tempered as Lorentz, did not explicitly make such a bold assertion, even though she did refer to the quanta a few times in her clearly, carefully, and cautiously written dissertation. That she was indeed thinking of magnetism as a quantum phenomenon follows only indirectly from one of the propositions at the end of her thesis: "The explanation for paramagnetism, as given by Kroo with the help of quantum assumptions, is unsatisfactory (J. N. Kroo, *Verh. d. Deutsch. Phys. Ges.* 1915, p. 452)" (Van Leeuwen, 1919, p. 118).[20] A true quantum understanding of magnetism would of course only become possible after the work of Ehrenfest's students George Uhlenbeck and Sam Goudsmit on electron spin, Wolfgang Pauli's formulation of the exclusion principle, and the development of a complete theory of quantum mechanics several years later. In 1919, Van Leeuwen's finding nevertheless did seem to provide yet another piece of evidence in support of the idea that nature must be quantized at the smallest scales.

2.6 Scooped

What Van Leeuwen and Lorentz apparently did not know was that the very same result – at least for the case of free electrons – had also been obtained already in 1911 by none other than Niels Bohr during his PhD research (Bohr, 1911). Expanding on Lorentz's electron theory, Bohr had concluded that "the presence of free electrons in a metal will give rise neither to diamagnetic nor to paramagnetic properties." That Lorentz and Van Leeuwen seemed unaware of this is understandable, given that Bohr's thesis was written in Danish and filed in the university archives, and that his results were not published in academic journals.[21] Or, as Van Vleck remarks in a footnote: "Many of Miss van Leeuwen's results were previously

[19] Van Vleck phrased the theorem as: "At any finite temperature, and in all finite applied electrical or magnetic fields, the net magnetization of a collection of electrons in thermal equilibrium vanishes identically."

[20] Original: "De verklaring, door Kroo met behulp van quanta-onderstellingen gegeven van het paramagnetisme van vaste lichamen, is onbevredigend (J. N. Kroo, *Verh. d. deutsch. phys. Ges.* 1915, blz. 452)."

[21] The English translation was only published in 1972. By then, the tradition of publishing theses in languages other than English had almost disappeared in many European countries.

obtained in Bohr's dissertation (Copenhagen, 1911), but this unfortunately is probably rather inaccessible to most readers" (Van Vleck, 1932, p. 94).

Interestingly, the roles of Bohr and Van Leeuwen were completely reversed in Van Vleck's 1977 Nobel lecture. That time, Van Vleck only mentioned Bohr's thesis work, and Van Leeuwen's work ended up in a footnote. The change is closely related to the shift in perspective that was already visible in the title of his lecture, "Quantum mechanics: The key to understanding magnetism." In 1932, Van Vleck praised the completeness of Van Leeuwen's critical analysis of the phenomenon of magnetism by asserting that, even though "other investigators had previously predicted zero magnetic susceptibilities under certain conditions, it remained for Miss van Leeuwen to review critically the whole subject of susceptibilities in classical theory" (Van Vleck, 1932, p. 95). In 1977, instead, Van Vleck focuses on the role of Bohr's thesis work ("the perhaps most deflationary publication of all time in physics")[22] in quantum developments, and suggests that this work may well have been "one reason why Bohr broke with tradition and came forth with his remarkable theory of the hydrogen spectrum in 1913" (Van Vleck, 1992, p. 354).

In fact, Van Vleck's shift in perspective already emerges from his 1963 interview with Thomas Kuhn: "One always thinks of its [quantum mechanics'] effect and successes in connection with spectroscopy, but I remember Niels Bohr saying that one of the great arguments for quantum mechanics was its success in these non-spectroscopic things such as magnetic and electric susceptibilities" (Van Vleck, 1963). In his 1977 Nobel lecture Van Vleck discussed this observation in more detail (Van Vleck, 1992, p. 354):

> That year [1913] can be regarded as the debut of what is called the old quantum theory of atomic structure, which utilized classical mechanics supplemented by quantum conditions. In particular it quantized angular momentum [through the well-defined quantized electron orbits] and hence the magnetic moment of the atom [induced by the negatively charged electron revolving around the atomic nucleus] as was verified experimentally in the molecular beam experiments of Stern and Gerlach [Stern and Gerlach, 1922]. Hence there was no longer the statistical continuous distribution of [positive and negative] values of the dipole moment which was essential to the proof of zero magnetism in classical theory.

Van Vleck continued by briefly mentioning the work of Langevin who had in 1905 concluded that para- and diamagnetism could arise in classical-mechanical systems in thermal equilibrium, a result seemingly contradicting the work of Bohr and Van Leeuwen. The caveat here was that Langevin had unknowingly added a form of quantization to the system, Van Vleck explained. In his own words: "When Langevin assumed that the magnetic moment of the atom or molecule had a fixed value μ, he was quantizing the system without realizing it, just as in

[22] "Deflationary" in the sense that the work completely deflated the role of classical physics in explaining magnetism.

Moliere's [sic] Bourgeois Gentilhomme, Monsieur Jourdain had been writing prose all his life, without appreciating it, and was overjoyed to discover he had been doing anything so elevated." What Van Vleck did not mention here was that Van Leeuwen had already drawn this conclusion in her 1919 thesis.[23]

In retrospect it seems rather disappointing that while Van Leeuwen's finding seemed to provide an additional piece of evidence for the idea that nature is quantized at its smallest scales, the very similar finding by Bohr in 1911 may in fact have inspired Bohr to introduce his quantized model of the hydrogen atom in the first place. It also makes one wonder if Van Leeuwen, Bohr, and Lorentz ever discussed these matters. In the spring of 1919 Bohr did spend two weeks in Leiden at the invitation of Ehrenfest. Bohr, who had supervised a major part of Hendrik Kramers' thesis work during the three years prior, participated in Kramers' PhD defense (Dresden, 1987, pp. 110–113; Klein, 2010, pp. 308–311; Van der Heijden, 2021, pp. 210–211). But the two men also had lengthy discussions, took long walks, talked to Lorentz, and visited Kamerlingh Onnes' laboratory. Available evidence, however, does not clarify whether Van Leeuwen was involved in any of these activities. What is certain, though, is that her work is captured in what from the late 1930s onwards came to be known as the Bohr–Van Leeuwen theorem.[24]

2.7 Not One of the Boys; Not One of the Women

Van Leeuwen might have been scooped by Bohr, but at the same time, one might just as easily interpret this situation as a sign that her thesis work was on par with that of the well-known Bohr. From this perspective her work seemed like an excellent start for a promising career in physics. Yet, while Burger and Rubinowicz were soon promoted to full professorships, Van Leeuwen struggled to find a position.

She had always been a bit of an outsider among the young theoretical physicists in training in Leiden. Her PhD supervisor Lorentz lived in Haarlem, where he had become the director of the small physics laboratory of the Teylers Museum in 1909.[25] His successor in Leiden, Ehrenfest, had since his arrival in 1912 gathered

[23] A footnote in his 1932 book suggests that he was aware of her work: "She [Van Leeuwen] mentions and discusses at some length the fact that a susceptibility different from zero can be obtained if in statistical mechanics there is imposed some auxiliary condition (*Nebenbedingung*) which restricts to a definite numerical value some other function of the dynamical variables of the assembly of molecules besides its total energy. There is, however, no known justification for the imposition of such an extra condition in assemblies such as are encountered in the theory of magnetism" (Van Vleck, 1932, pp. 94–95).

[24] Van Vleck spoke of the Van Leeuwen theorem in 1932, but by 1927, Rice physicist Claude Heaps spoke of the Bohr–Lorentz–Van Leeuwen theory (Heaps, 1927) In 1937, geophysicist Edward Hulburt mentioned an argument by "Bohr (thesis) and by Van Leeuwen" (Hulburt, 1937). From then on, both names seem to have been attached to the work increasingly often, until this label became common use after World War II.

[25] Lorentz combined this post with his Leiden professorship until he formally retired from Leiden University in 1912. He did continue to give his 'Monday Lectures' and to act as a PhD supervisor until the early 1920s.

a circle of promising students around him such as Jan Burgers, Dirk Jan Struik (who would become a renowned mathematician in the US), Dirk Coster (who would become professor of physics in Groningen), and Kramers, who would later work with Bohr. But Van Leeuwen was not part of this close-knit group who would visit Ehrenfest at home, attend colloquia in the study of Ehrenfest's large house, and help Tatiana Ehrenfest-Afanassjewa in the garden. Her correspondence with the Ehrenfests is limited to a handful of postcards, and her name only rarely appears in memoirs or interviews with Ehrenfest's students (Burgers, 1962; Casimir, 2004, p. 94; Rowe, 2018).

An illustration of her relative outsider position can also be seen in Ehrenfest's correspondence from 1917. During the summer of that year and in a rather unusual move, Ehrenfest visited his student Jan Burgers' parents in their modest house in Arnhem. There, he also met Burgers' younger brother Willy, who was about to begin studying in Leiden, like his elder brother. In the aftermath of the visit an inspired Ehrenfest wrote a series of postcards to the two brothers expressing his hope that they would come live in a room in the Witte Rozenstraat, close to his own large house, where they could then work in his large study. In fact, before the new semester began, an overly enthusiastic Ehrenfest had already reserved that room and paid the landlady one month's rent in advance. It was the room where the Van Leeuwen sisters had lived until Nel's recent marriage. Apparently, Jo van Leeuwen planned to leave the apartment: her father had recently died and she intended to move back to The Hague to live with her mother, Ehrenfest explained briefly on one of the postcards to the brothers.[26] Almost casually his remark thus captures the losses that Jo was experiencing: her father dead, her younger sister Nel moving in with her newly-wed husband Nordström, and she herself having to depart from her room in Leiden.

Perhaps Ehrenfest kept his distance because he did not want to interfere with Lorentz, Van Leeuwen's supervisor, whom he deeply admired. It may also be that Ehrenfest – born as the youngest child in a family of five sons, and friends with famous physicists including Einstein, and later also Bohr, Schrödinger, and Pauli – was unconsciously inclined to see physicists in a gender stereotypical way. Such stereotypical views may have been exacerbated in the period after moving to Leiden when he, appointed as professor, and his wife Tatiana Ehrenfest-Afanassjewa, staying at home, no longer managed to live up to their ideal of working and studying together as two equals (Van der Heijden, 2024). It may also be that there was simply a bit of an *incompabilité d'humeur* (clash of personalities) between the extraverted, demanding, humorous, but also sharp-witted Ehrenfest and the somewhat reserved Van Leeuwen, who moreover was a couple of years older than most of Ehrenfest's PhD students.

[26] Ehrenfest to Burgers, August 27 and 29, 1917, Burgers Archive, Delft University of Technology.

In any case, it was Lorentz who supported Van Leeuwen most during her graduate studies, as is also clear from his correspondence. Just after World War I broke out in September 1914, in a note to Ehrenfest, Lorentz suggested that Van Leeuwen should become Ehrenfest's assistant. Such a temporary assistant position entailed giving lectures if necessary, writing lecture notes, assisting with a professor's correspondence, etc., in exchange for a small income. Lorentz wrote: "The assistant position may become temporarily vacant now that Droste has left. We could suggest [Adriaan] Fokker as his successor with the announcement that he has been called to arms and temporarily appoint Miss van Leeuwen as assistant. She would then resign when demobilization takes place."[27] Probably to avoid giving his successor the impression that he still wanted to manage university matters from Haarlem, Lorentz added that "it seems to me that you will have to choose an assistant from now on." Yet, when a few days later it turned out that temporary cutbacks prevented the university from employing new assistants, Lorentz immediately pressed Ehrenfest to find another solution for Van Leeuwen. "Can't the University Fund provide a small amount of money so Miss van Leeuwen can then take on the Reading Room? You can write to Kluyver about this," he wrote.[28]

Fortunately, Van Leeuwen got the assistant position and was able keep it until Fokker was demobilized in the autumn of 1917. In September 1917, she herself reminded Lorentz that she had promised to resign as assistant upon Fokker's return. Perhaps she also felt obliged to give up the position because unemployment rates were rising and the sentiment in Dutch society was that women should not "steal" jobs from men. Lorentz was of another opinion, however. He wrote to Ehrenfest: "Miss van Leeuwen asks me whether, now that Fokker has been granted study leave [from his mobilization], the time has come for her to resign as assistant. It seems to me that we can leave the situation as it is now for another six months. Fokker only has leave of absence during that time. Besides, he is wealthy enough and does not need the money and will want to devote himself to his studies first."[29]

Although previous authors have assumed that Fokker and Van Leeuwen both agreed with Lorentz's proposal for Van Leeuwen to keep the assistant position for a while longer (Berends and Van Delft, 2021), archival documents suggest otherwise. In October 1917, she moved to Deventer to teach physics and cosmography at the local HBS for three months, most likely at the recommendation of Lorentz's

[27] Lorentz to Ehrenfest, September 3, 1914, Ehrenfest Archive, Rijksmuseum Boerhaave, Leiden.
[28] Lorentz to Ehrenfest, September 8, 1914. Ehrenfest Archive, Rijksmuseum Boerhaave, Leiden.
[29] Lorentz to Ehrenfest, September 23, 1917, Ehrenfest Archive, Rijksmuseum Boerhaave, Leiden. Original: "Mej. van Leeuwen vraagt mij of, nu Fokker studieverlof heeft gekregen, niet de tijd is gekomen dat zij ontslag neemt als assistente. Mij dunkt dat we de toestand nog een half jaar zoo kunnen laten als hij nu is. Fokker heeft slechts voor die tijd verlof. Bovendien is hij vermogend genoeg en zal hij zich eerst aan zijn studie willen wijden."

son-in-law, Wander de Haas, who had taught there in prior years.[30] Afterwards, she indeed returned to The Hague, presumably to live with her mother, as Ehrenfest had written.[31] It is unclear if Van Leeuwen also worked as a teacher in 1918 and after her thesis defense on January 20, 1919. What can be verified is that she worked as a physics teacher in Delft, at the Gemeentelijk Gymnasium, from September 1919 until the summer of 1920.[32] Starting September 1, 1920, most likely with Lorentz's support, she became employed as assistant at the TH Delft, one of the first women to be hired by the institution.

That Van Leeuwen herself was not unaware of her unique position as one of the few women in her field is revealed by the last of the 13 propositions at the end of her dissertation. As is common in Dutch theses, this proposition does not pertain to a result from her thesis or to a physical phenomenon and it reads[33]: "On the basis of statistical material collected on the study of women (see G. Heijmans: *Die Psychologie der Frauen*, 1910, pp. 105–155, [Heidelberg: Winter]) no conclusion can be drawn, at least for the time being, as to the degree of suitability of women for scientific work (Van Leeuwen, 1919, p. 119)."

2.8 Assistant at the Technical College of Delft

In Delft, Van Leeuwen's main task was to supervise the physics laboratory courses in the Faculty of Electrical Engineering.[34] The job must, especially at first, have left her little time to pursue theoretical work on magnetism. Moreover, she was now truly a pioneer-woman. None of Lorentz's other female graduate students pursued an academic career with a formal position at a university or research institute. In the 1920s Johanna Reudler and Eva Bruins helped compile Lorentz's lecture notes and turn them into scholarly books that were translated to German by Lorentz's daughter Berta (Lorentz, 1921, 1927, 1928). Berta de Haas-Lorentz published a book herself as well, in Dutch, on thermodynamics (De Haas-Lorentz, 1938), and a paper on surface currents in superconducting materials that is still regularly cited (De Haas-Lorentz, 1925; Fossheim and Sudbø, 2005, pp. 141–143). But such

[30] Gedenkboek Deventer Hogere Burgerschool 1864–1939, Delpher.

[31] On December 22, 1917, she registered at Bentinckstraat 28, Den Haag, where she had previously lived with her parents; Haags Gemeentearchief, Den Haag. A postcard suggests that she still lived there with her mother in December 1921: Van Leeuwen to the Ehrenfests, December 27, 1921. Ehrenfest Archive, Rijksmuseum Boerhaave, Leiden.

[32] Annual report 1919–1920 of the curates of the Stedelijk Gymnasium Delft: "Curatoren (scholarchen) van de Latijnse School en Regenten van het Fraterhuis en het Stedelijk Gymnasium (sinds 1950 Grotius Gymnasium), 1610–1966," inventaris nr. 30, Stadsarchief Delft.

[33] Original: "Uit statistisch materiaal, verzameld over het studeeren der vrouwen (zie G. Heijmans: *Die Psychologie der Frauen*, 1910, blz. 105–55) kan althans voorloopig nog geen besluit worden getrokken over de mate van geschiktheid der vrouw voor wetenschappelijk werk."

[34] Applied physics did not become an independent study programme at TH Delft until 1928, although physics was part of all other engineering programmes.

projects were undertaken from home where Berta devoted much of her time to household duties and taking care of the children.[35]

This outcome was not surprising since traditional views on gender roles kept a strong foothold in the Netherlands. On the one hand, Dutch women had finally obtained the right to vote in 1919, thanks to the fighting spirit of Jacobs and her Association for Women's Suffrage (Feinberg, 1999; Bosch, 2005). On the other hand, 1924 brought a severe backlash for working women when a new law, confirmed by Royal Decree, stipulated that women were to be honorably discharged from public service and government jobs on the day of their marriage. The law effectively closed off roles as teacher, university lecturer, and researcher to married women, with most private companies following the government's example. Women thus had to choose between working and staying single or marrying and losing their job. As a result, slightly over 90% of the Dutch married women holding a PhD in physics were unemployed in the 1930s (Kirejczyk, 1993, pp. 240–241).

It would take until 1957 for this discriminatory law to be abolished, and for Dutch married women to – very slowly – return to the job market. For Jo van Leeuwen, this change came too late – if she had wanted to marry at all, that is. Little is known about how Van Leeuwen thought and felt about these matters though. For many of her contemporaries, she came across as someone who kept to herself, and they often described her as introverted and somewhat reserved. A former physics student from Delft, for example, recalls that Van Leeuwen was more distant than the other members of the scientific staff, stating that "the personal element was lacking in interactions with her."[36]

A former technician, who worked in the same "beautiful and cosy building with nooks and crannies" as Van Leeuwen, the Laboratory for Technical Physics at the Mijnbouwplein in Delft, remembers that she was also friendly:

> As a boy of about nineteen, I started my work in the building in the recently established "Electronic Repair Shop" . . . and went on to work in the "Calibration Room." . . . It was there that . . . I first met with Miss van Leeuwen, because the equipment of her laboratory class also had to be calibrated. It consisted of multimeters, a lot of tube voltmeters, low-frequency tone generators, oscilloscopes, stabilized power supplies and so on.. . . Miss van Leeuwen addressed everyone as "Sir," including me, the just twenty-year-old. Whenever I returned the calibrated equipment, she often stopped for a chat and asked if I had noted anything unusual related to her equipment. She almost always sat at a laboratory table that had been converted into a desk.[37]

Van Leeuwen did like manners though, he adds.

[35] In 1910, while still a graduate student, Berta Lorentz married Wander de Haas, who would become professor of experimental physics at Leiden University, and with whom she had two daughters and two sons.
[36] Dr. Ir. A.E. Pannenborg, personal communication by letter, dated May 31, 2014.
[37] Loek Kraamer, personal communication by email, February 29, 2016.

Nobody was afraid of her, not even the students I think, but you had to watch your step. I remember a master's thesis student explaining the apparatus he had designed while standing with his hands in his pockets. And yes, Miss van Leeuwen remarked: "Mr v.d. *** would you please take your hands out of your trouser pockets." It did not sound bitter or reproachful, rather more like a friendly request. Yet the face of the person addressed momentarily changed colour.

While thus supervising the physics laboratory, Van Leeuwen also remained in close contact with Lorentz and other members of the Leiden Physics Department. In 1925, together with Kramers and other Leiden colleagues, she organized a symposium commemorating the 50th anniversary of Lorentz's doctorate. It was attended by Einstein, Marie Skłodowska Curie, and quite a few other well-established physicists (see Figure 2.3). On this occasion she also wrote an article for the *Nieuwe Rotterdamsche Courant*, a Dutch national newspaper, about Lorentz's scientific work and mentorship. The article shows affection and admiration for her former advisor whom she describes as kind and modest. Van Leeuwen recalls, for example, how she and the other students slowly realized that those discoveries and findings that were discussed during his lectures without him mentioning their discoverer's name, as was Lorentz's custom, were made "by professor Lorentz himself." In short, for her and for the other students, Lorentz was "not just this great researcher, but also this kind, cheerful man with a strict devotion to duty, amiable simplicity and warm interest in all those around him" (Van Leeuwen, 1925).[38]

In addition, Van Leeuwen continued exchanging letters with Lorentz about theoretical problems in magnetism until at least 1927, one year before his death, when she suggested to him to include some of these problems in the notes of his Leiden "Monday Lectures" that he was compiling at the time with the help of Bruins, Reudler, and his daughter Berta.[39]

In Delft, meanwhile, it did not go unnoticed that Van Leeuwen, alongside her work on the laboratory courses, was still engaged in theoretical research on magnetism. In the early 1930s, for instance, Bram van Heel, professor of optics in Delft, composed a ballad for the annual "lab evening" of the Faculty of Applied Physics in which each of the more than 20 stanzas light-heartedly sang the praises of the work of a staff member.[40] Whether her colleagues valued what she was working on, though, cannot be deduced from the part for Van Leeuwen that only playfully refers to quantum theory and reads (translated):[41]

[38] Original: "Lorentz, voor zijn leerlingen, was niet alleen de groote onderzoeker, maar ook de vriendelijke, opgewekte mensch met strenge plichtsbetrachting, beminnelijken eenvoud en warme belangstelling voor allen om hem heen."

[39] Van Leeuwen to Lorentz, April 26, 1927, 364 – Prof. Dr. H. A. Lorentz Archive, Inventaris nr. 47, Noord-Hollands Archief, Haarlem.

[40] 433 – A. C. S. van Heel en H. G. van Heel-Meerburg, 1903–2001 Archive, Stadsarchief Delft, Delft.

[41] The original Dutch:

Figure 2.3 Group picture of the attendees at the celebration of Lorentz's golden doctorate on December 11, 1925. Jo van Leeuwen is in the third row, to the left of Einstein. Lorentz's daughter Berta is sitting next to Marie Skłodowska Curie, and Skłodowska Curie is sitting to the right of Lorentz. Image courtesy of the North Holland Archive/1100 – Beeldcollectie van de gemeente Haarlem, inv. nr. 21303.

Miss van Leeuwen with her magnets
Is perspi-sweating on the theory
That is the the-ory
That is the the-ory
That is the the-ory . . .. of Heisenberg

2.9 Reader at Last

Van Leeuwen held the position of assistant for more than 20 years before becoming principal assistant in theoretical and applied physics in 1943. Even then she continued her research on magnetic phenomena and, among other things, proposed a model for the reduction of permeability in ferromagnetic metals that, in contrast to

"Juffrouw van Leeuwen met haar magneten zit op de theorie te transpizweeten Dat is de thė-orie Dat is de thė-orie Dat is de thė-orie . . . van Heisenberg" previously proposed models, agreed well with experimentally measured data. She notably gave a lecture on the subject at a symposium on ferromagnetism in Delft in April 1947 (Van Leeuwen, 1947).

Shortly thereafter, at age 59, Van Leeuwen was promoted to reader in theoretical and applied physics. Her appointment not only came late by present-day standards but also in the eyes of some of her contemporaries, as can be deduced from a congratulatory note that Dirk Coster, professor of physical meteorology at the University of Groningen in the Netherlands, sent her. On October 25, 1948, Coster, who in the 1910s had been one of Ehrenfest's promising students, wrote: "Dear Miss van Leeuwen, I warmly congratulate you on your appointment at the TH [Delft]. Late, but luckily not too late, you have found at least partial recognition for your talents. Those who know you will have read the announcement with approval. I would also like to congratulate you on behalf of my wife."[42] The careful phrase "partial recognition" makes one wonder what career she could have pursued had she not been trapped in a position centred around guiding students towards a successful future – male students who would never encounter the hurdles with which she had been confronted.

Within two years two other women – Antonia Korvezee, who became a reader in physical chemistry in 1948, and Jentina Leene, who obtained a position as reader in fibre technology in 1949 – would receive a similar promotion at the TH Delft. The threefold elevation was perhaps less of a break with traditional views than a pragmatic measure. As science historian Frida de Jong noted: "Shortly after the war it was difficult for the TH to get academic staff. Wages were low compared with those in industry and laboratory facilities were less. At that time, shortly after each other, three women were appointed lecturer (. . .) These three ladies were all from an older generation, trained with a Ph.D. well before the war, and unmarried" (De Jong, 1997, p. 238).

For Van Leeuwen it meant that she was finally allowed to lecture. The 1952 "Programme of lectures of the Technical College Delft" informs us that Miss Dr H. J. van Leeuwen lectured on ferromagnetism and principles of special relativity theory. She also continued to run the advanced physics *practicum* (laboratory course) and many former colleagues later testified that the way in which she organized and ran this course for third-year students was highly appreciated by both her students and her colleagues. Some of these last ones had even attended "her" laboratory course as students themselves, before becoming staff members at the university. One of them, Jan Berend Westerdijk, addressed Van Leeuwen in his

[42] Coster to Van Leeuwen, October 25, 1948. Collectie-Coster, Groninger Archieven, Archief van de Senaat en de Faculteiten, Groningen. Original: "Zeer geachte Mejuffrouw van Leeuwen, Van harte wens ik U geluk met Uw benoeming aan de T.H. Het is wel laat geworden, maar gelukkig niet te laat dat U althans gedeeltelijk erkenning van Uw bekwaamheden hebt gevonden. Zij, die U kennen, zullen het bericht met instemming gelezen hebben. Ook namens mijn vrouw breng ik de gelukwensen over."

inaugural speech when he became professor of technical physics at the TH Delft in 1952, shortly before Van Leeuwen's retirement (Westerdijk, 1952, p. 20):

> Distinguished Miss van Leeuwen, It makes me happy, before you bid us farewell, to be able to express to you my great admiration for the way in which, during so many years, you have trained our students to become independent learners and thinkers in your practical classes . . . The often high-level graduation work in the department would never have been possible if the important "practical of Miss van Leeuwen" had not been constantly modernized and managed by you in such a dedicated manner.

2.10 Last Years

What had happened to her younger sister, Nel, during all those years? Not long after the young Nordström-Van Leeuwen family moved to Finland, two more children were born and soon thereafter, at the end of 1923, Nordström died from pernicious anaemia, perhaps induced by his experiments with radioactivity. Ironically, this meant that Nel, as a widow, would have been allowed to pursue a career in the Netherlands, even after the 1924 Royal Decree. Her distance from the field of physics had become insurmountable, however, and she decided to spend the rest of her life in Finland, where she worked as a translator and language teacher.

In 1923, Tatiana Ehrenfest-Afanassjewa mentioned Nel's activities in a letter to her husband, who often complained about the high costs of the large Ehrenfest-Afanassjewa household in Leiden. "I would like to have been able to do that; and most of all to win such assignments," Afanassjewa commented on Nel's jobs (Van der Heijden, 2021, p. 248). For Ehrenfest-Afanassjewa, forced into the conventional roles of a mother and professor's wife, it seemed a dream to earn a salary as Nel had done, let alone to secure a formal position at a Dutch Technical College as Jo had managed to do.

The two sisters themselves stayed in touch via visits, and through letters and postcards.[43] A few of these cards have been preserved, dating mostly from the last period of their lives, by which time Jo van Leeuwen had moved to Huyse van Sint Christoffel, an old-age home for ladies in the city centre of Delft (nowadays an apartment complex). She lived there from 1960 until her death in 1974 "in the midst of many kind ladies in rooms on two floors enclosing a beautiful and big garden."[44] There is no indication that she was still scientifically active during these years, but postcards and letters preserved in the City Archives of Delft suggest that she kept

[43] H. Kristjankroon, copies of postcards and personal communication.
[44] J. van Leeuwen to T. Ehrenfest-Afanassjewa, June 17, 1961, Ehrenfest Archive, Rijksmuseum Boerhaave, Leiden. Original: 'Ik leef hier temidden van vele aardige vrouwen in een kring van kamers in 2 lagen om een mooie en grote tuin.'

informed about and in some cases participated in important events in the lives of her former colleagues.

Her sister Nel survived Jo by only half a year and died in Finland in the late summer of 1974. Like much else, whether the two Van Leeuwen sisters – one single with a scientific career and the other widowed and self-supporting with children – ever discussed the different obstacles and hurdles they had encountered and how these had affected their own lives and careers, we will probably never know.

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