BIOGRAPHICAL MEMOIRS

HENDRIK BRUGT GERHARD CASIMIR

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PROFESSOR Dr. Hendrik B. G. Casimir, a leading physicist of the twentieth century, died 4 May 2000 in the Dutch town of Heeze, where he had lived for many years. He is best known for his theoretical work on the long-range character of the London–van der Waals force between atoms and molecules; this work led to his assertion that two flat closely spaced parallel conducting plates would be mutually attracted due to modification of the zero-point modes of the electromagnetic field between the plates, and has been described as one of the least intuitive consequences of quantum electrodynamics. Casimir's idea that the modification of the zero-point structure of a system by its boundaries could lead to observable phenomena has become one of the most important concepts of modern theoretical physics.

Professor Casimir was born in The Hague on 15 July 1909. He was a student at the University of Copenhagen from 1929 to 1930, and received a D.Sc. at Leiden, the Netherlands, in 1931 under the supervision of Paul Ehrenfest. Casimir's dissertation addressed the quantum mechanics of an asymmetric rigid rotator. In this context he introduced the concept of the "Casimir operator," which, in addition to its original intrinsic importance to the fundamentals of quantum theory and mathematics, is important to modern particle theory. So begins Professor Casimir's brilliant career.

I must say at the outset that I never met Professor Casimir; the random walk of my career has led me in a number of directions in regard to my physics research, and with each direction I have encountered his influence in a wide breadth of subfields of physics, from hyperfine structures of atoms, to experimental techniques in low-temperature physics. My one direct contact with Professor Casimir was his writing me a letter of congratulations for my success at measuring the "Casimir force" with significantly higher accuracy than had ever been achieved before. Because this letter illustrates his wit and passion, I reproduce it here:

> Dear Dr. Lamoreaux
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> You will understand how much I enjoyed reading your beautiful confirmation of a formula I derived half a century ago. I am no longer an expert in the field, but it seems to me that you have certainly done far better than has been done before.
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> However, I believe there have been some attempts after Sparnaay 1958. An amusing one, due to Sparnaay and Jochems, was published in a rather impossible place: M. J. Sparnaay and P.W.J. Jochems, Third International Congress on Surface Activity Cologne 1960 Vol. 2 sect.B/111/1 nr 56 p. 375.
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> In this experiment a thin wire carries at its end a little sphere of gold. When this is moved towards a flat metallic plate there is a critical

> distance at which the sphere flips and hits the plate. This was observed many times—initially while making contacts to a microcircuit—and the critical distances were at least qualitatively in agreement with theory. I like the idea that the Casimir effect may render service in soldering leads to circuits.
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> Your sincerely,
> (signed) HBG Casimir
> [Received February 1997]

There are two books that describe Professor Casimir's work and his life. On the occasion of his eightieth birthday, a collection of essays was prepared: *Physics in the Making: Essays on Developments in Physics in the 20th Century* (edited by A. Sarlemijn and M. J. Sparnaay [Amsterdam: North-Holland, 1989]). Casimir's autobiography, *Haphazard Reality* (New York: Harper and Row, 1983) paints a vivid and insightful picture of the development of modern physics. These two books are complementary in that the first describes the development of physics and the milieu of Casimir's life in rather broad terms, while the second speaks directly of his interactions with the principal architects of modern physics and his transition to industrial research and management. Recently, on the occasion of his ninetieth birthday, a special issue of *Comments on Modern Physics* (1 [2000]: 171–378]) addressing the subject of Casimir forces was prepared, and appeared in print just about the time of his death. He contributed a short note to this issue. A bibliographic selection of his publications is also presented.

Professor Casimir began his professional career in the winter of 1931 as Ehrenfest's assistant; at that time, Ehrenfest was already suffering from the depression that eventually led to his suicide, and he recommended that Lise Meitner hire Casimir as a temporary replacement for Max Delbrück. Casimir was taken by the idea because he was interested in the new field of neutron physics. During his stay in Berlin (of less than two months' duration) he was able to interpret the perturbations of the hyperfine structures of a number of mercury atomic emission lines.

From 1932 to mid-1933, Casimir was Wolfgang Pauli's assistant at Zürich, replacing Rudolf Peierls, who had left to work with Fermi. During this period, Casimir worked on the relativistic theory of the electron, in particular, evaluating deviations of the Klein-Nishina equation in the case of bound electrons. Casimir invented a number of mathematical tools to attack the problem. One in particular is still referred to as the "Casimir Trick," and is a familiar procedure in the methods of trace formation and projections using products of Dirac matrices. The ultrarelativistic limit of the electron wavefunction in a Coulomb field is referred to as the Casimir limit.

In August 1933, Professor Casimir married the experimental physicist Josina Jonker. Earlier that year, around Easter, he had received an urgent message from Ehrenfest to return to Leiden; the message ended with the cryptic sentence, "Put your broad shoulders under the wagon of Leiden physics." While Casimir and his bride were returning from Copenhagen, he received news of Ehrenfest's death. Casimir answered his call and temporarily filled Ehrenfest's post until the arrival of Kramers in 1934. It was during this period (1933–36) that Casimir wrote his famous book *On the Interactions between Atomic Nuclei and Electrons* (San Francisco: W. H. Freeman, 1963) as an essay entry for the Teyeler's Tweede Genootschap Prize, which he won in 1936. In this book, the principles of atomic hyperfine interactions are explained in general, and the particular case of the electric quadrupole moment interaction represents Casimir's own original work. Also during this period, he had become interested in low-temperature physics, and worked with C. J. Gorter on the thermodynamics of superconductors. In addition, he assisted his wife, who was working in the Leiden cryogenics laboratory. In *Haphazard Reality*, he describes an example of his working with her, in youthful enthusiasm, observing a sensitive magnetometer for a whole night (to avoid the magnetic perturbations associated with daytime activities) to see if they could detect any decay of a persistent current in a superconductor.

In 1936, W. J. de Haas, co-director with W. H. Keesom of the Leiden cryogenics laboratory (they were jointly appointed on the passing of Heike Kamerlingh Onnes, the founder and original director) offered Casimir the position of senior assistant in his laboratory. During the next six years, Casimir worked on experimental low-temperature physics, which included the study of the adiabatic demagnetization of paramagnetic materials to achieve milli-Kelvin temperatures. With F. K. Dupré, he formulated the concept of a spin temperature to describe the equilibrium among the magnetic moments of a sample; this temperature can be different from that of the lattice in which the spins are embedded. Casimir and G. J. Van den Berg discovered the so-called Kondo effect. In 1938, based on an earlier suggestion by Peierls, Casimir showed that the heat conductivity of a pure single crystal would depend on its physical dimensions because of phonon wavelength limitation and phonon scattering at the crystal boundaries—anticipating in some ways his later and most significant work.

Casimir's last experimental effort involved measuring the temperature dependence of a magnetic field penetration into a superconductor. He did not have time to perfect the technique (it was eventually used with great success by others), but was able to conclude that previous measurements were questionable. The Nazi forces occupied the

Netherlands on 10 May 1940; Casimir's paper describing his technique was received by the journal *Physica* on 28 September 1940. Leiden University was closed late that November by the Nazi occupation in answer to the protest by the faculty and a student strike against the National Socialists' dismissal of the university's Jewish faculty members (the cryogenics laboratory continued to operate as usual).

Because of difficulties in his relationship with de Haas, fomented by the ordeal of Nazi occupation, Casimir left Leiden to take a position with the Philips Company research laboratories. During the occupation, the research laboratories were left largely alone. In *Haphazard Reality*, Casimir explains that "the [Nazis] must have realized that it was useless to try to have the Dutch people do military work. Sabotage was to be expected—and in research you do not even need active sabotage to get no results. On the other hand, as long as the [Nazis] expected to win the war, there was some point in preparing for future innovations."

Professor Casimir remained at Philips after the war, largely giving up his academic career (he remained an associate professor at Leiden). In *Haphazard Reality*, Casimir vaguely describes his leaving academia as a choice between dealing with idiosyncratic individuals in the academic setting versus dealing with the idiosyncrasies associated with a corporate bureaucracy; the latter was preferable and certainly of higher stakes. Nonetheless, Casimir was chastised by some members of the academic community, in particular by Pauli, who considered Casimir to be his most talented understudy; Pauli later referred to him as "Herr Direktor," and felt he was lost to physics. Casimir eventually became co-director of the Philips research laboratory in 1946, and member of the board of management in 1956. He stayed at Philips until his retirement in 1972.

Casimir does not say much about the operations of Philips, but he was clearly very happy working there. In addition, regarding his personal life, his marriage is described as having been extremely happy; he had five children, four daughters and a son.

Professor Casimir in fact did some of his most significant and brilliant work while at Philips. His colleagues J.Th.G. Overbeek and E.J.W. Verwey, in the course of their experimental work on the stability of colloids in solution, had concluded on the basis of semi-classical arguments that the usual form of the London–van der Waals interactions between neutral atoms or molecules needed a correction factor, decreasing the usually assumed interaction for increasing distances. They approached Casimir and his coworker D. Polder, and asked if they could explain what was going on. Eventually, Casimir and Polder provided a complete theoretical analysis that explained the experimental observations. This analysis took into account the finite propagation time of light between the interacting particles. Casimir further refined and simplified the calculational techniques, based on a hint provided by Niels Bohr, by considering the interaction of the atoms or molecules with the zero-point photons in a cavity. The extension to the case of two parallel plates was then obvious to him; "the" Casimir force is the attraction of two flat, parallel conducting plates due to the modification of the zero-point fluctuations of the electromagnetic field between the plates.

The idea that the boundaries of a system can affect the accessible zero-point fluctuations, and thereby alter the observable properties of the system, has widespread interest in physics, from Hawking radiation that allows black holes to evaporate, to issues of quark binding in quantum chromodynamics. Although Casimir's original article was a mere three pages in length, the number of journal pages addressing "the" Casimir force alone is certainly in the tens of thousands.

Professor Casimir's work on this subject was done between 1946 and 1949. Some years later, at a conference, he told Pauli about his work on the attraction of two flat plates. "Complete nonsense," Pauli said, but Casimir persisted, and Pauli finally admitted defeat by calling Casimir a *Stehaufmanderl*—German for a toy that might roughly be described in English as a tippy-top—and thenceforth did not refer to Casimir as "Herr Direktor." We can guess that Casimir was amused.

Professor Dr. Hendrik B. G. Casimir was one of the most original and deepest thinkers of the twentieth century and a true universal scientist. He participated in a large number of national and international science foundation committees. He was awarded six honorary degrees by universities outside the Netherlands. In addition, he was president of the European Physical Society from 1972 to 1975.

He received numerous awards and prizes, most recently the George E. Pake Prize from the American Physical Society at its 1999 Centennial Meeting, with a citation for his "excellence as a leader of industrial physics at Royal Philips Electronics and for fundamental contributions to the foundations of quantum mechanics and solid state physics."

Elected 1971

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