Wien, Wilhelm Carl Werner Otto Fritz Franz | Encyclopedia.com

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(*b*. Gaffken, near Fischhausen, East Prussia [now Primorsk, R.S.F.S.R.], 13 January 1864; *d*. Munich, Germany, 30 August 1928)

theoretical and experimental physics, philosophy of science.

Life. Wien was the only child of Carl Wien, a farmer with land in Gaffken, and Caroline Gertz,[1] both of whose families were descended from ancestors in Mecklenburg. When Wilhelm was two, they left Gaffken, which was no longer capable of supporting them, and moved to a smaller farm, Drachenstein, in the district of Rastenburg, East Prussia, where Wien spent his youth[2] He frequently rode through the fields with his father, who was confined to a wagon because of a spinal ailment, and thus Wien early learned about agriculture – in which his mother assumed the bulk of the family's responsibilities.

Wien was especially close to his mother, whose excellent knowledge of history and literature stimulated his interest in those subjects. An introvert, like his father he made no friends during his early childhood. He learned to ride, swim, and skate; and, as was then customary, a woman was engaged to give him private lessons in French, which he spoke before he was able to write his native language. In 1875 Wien's parents sent him to the Gymnasium in Rastenburg; but he had little inclination for study, preferring to wander through the fields. Furthermore, his preparation, especially in mathematics, was deficient; and in 1880 he was taken out of this municipal school, which was considered by Wien to be democratic, and sent home to learn agriculture. He compensated for his lack of academic instruction through private tutoring (in mathematics he had an outstanding teacher in Switalski) and then entered the Altstädtisches Gymnasium in Königsberg, from which he graduated in 1882, in less time than was usual.

Encouraged mainly by his mother, Wien enrolled at the University of Göttingen in the summer of 1882 to study mathematics and natural sciences. He was not, however, very much taken with what he learned in his mathematics course. Also, being of an independent spirit, he found the lavish life in the student societies distasteful and left the university after only one semester to travel through the Rhineland and Thüringen. Wien returned home with the intention of becoming a farmer but was soon discontented with the training required. He therefore resumed his studies, this time in mathematics and physics at the University of Berlin. In the winter of 1883–'1884, after two semesters, he entered Hermann von Helmholtz' laboratory, where he "really came into contact with physics for the first time." During the summer semester of 1884 Wien learned "a great deal" studying under G.H. Quincke at Heidelberg, then resumed his training under Helmholtz in Berlin. In his second semester as a physics student Wien was given the subject of his doctoral dissertation, the diffraction of light when it strikes a grating. After two more semesters, in 1886, he was awarded the doctorate, although he did not receive a good grade on his final examination.

In the summer of 1886 Wien went to Drachenstein to help his parents reconstruct some buildings that had been destroyed in a fire. Once again he began to consider becoming a farmer. August Kundt, who in 1888 became Helmholtz' successor at the University of Berlin, and Helmholtz himself, who at the same time had been appointed the first president of the newly founded PhysikalischTechnische Reichsanstalt (PTR), reinforced Wien's doubts about physics, maintaining that as an only son he should take over his parents' property; if he wished, he could always pursue scientific research as a hobby. Fate soon decided the issue for Wien, who did not feel capable either of buying a horse or of communicating with farm workers: in 1890 drought forced his parents to sell the farm. Wien thereupon became an assistant to Helmholtz at the PTR in Charlottenburg and his parents moved to Berlin-Westend. Wien, more over, felt a period of his life come to an end, because his mother fell seriously ill, his father died suddenly the following year, and Bismarck was dismissed by the Emperor.

Even during the time he spent on the farm, Wien continued to study theoretical physics, arbitrarily selecting the problems he would investigate. At the Reichsanstalt, which in 1890 became the center of his professional activities, he conducted an unsuccessful series of experiments employing platinum foil, that sought to establish a new unit of light. In this dual concern with theory and experiment lay the seed of Wien's development into the rare physicist who possesses equally good knowledge of both areas. Wien in 1892 received the *venia legandi* at the University of Berlin with a work on the localization of energy. From 1894 to 1897, at the suggestion of Helmholtz. he also considered problems of hydrodynamics: specifically, the theory of sea waves and of cyclones.

Wien's independence enabled him to make his own choice of problems for study and soon bore fruit. In 1893 he demonstrated, in a highly original manner, the constancy of the products $\lambda.\theta$, given a shift of the wavelength λ and the corresponding change in temperature θ. In fact, his findings refuted Helmholtz' initial view that the radiation could no longer be treated in exclusively thermodynamic terms. Wien also published, in 1896, the theoretical derivation of a law of the energy distribution of the radiation, which differs only slightly from the currently accepted Planck law.[3]

In collaboration with his friend Ludwig Holborn, Wien executed a series of high–and low–temperature measurements from which he derived considerable satisfaction. Nevertheless, he was happy to receive an offer in 1896 from the Technische Hochschule of Aachen because Friedrich Kohlrausch, who had succeeded Helmholtz as head of the PTR, had drawn up a rigid plan of research that ran counter to Wien's need for freedom. Soon after reaching Aachen, in its gay society, Wien met Luise Mehler; they were married in 1898 and had four children: Gerda, Waltraut, karl, and Hildegard. In Aachen he continued research begun in Berlin, on Rontgen and cathode radiation, using the apparatus left by his predecessor, Philipp Lenard. The investigation of vacuum radiation of this kind was to constitute the principal area of Wien's research.

In 1899 Wien accepted a post as full professor at the University of Giessen but left after only six months to take up a similar position at the University of Würzburg, where he spent the next twenty years–the most eventful of his scientific career. His experiments, conducted with the aid of the rapidly improving methods of high-vacuum technology, encouraged him to turn his attention to a study of the decay periods of excited atoms (and ions), a topic that occupied the final years of his career.

Wien visited Norway, Spain, Italy, England (1904), Greece (1912), and the Baltic region (1918), in the latter of which he gave several lectures. In 1911 he was awarded the Nobel Prize in physics "pour des découvertes concernant les lois de la radiation de la chaleur" ; in his acceptance speech he voiced serious doubts about Planck's radiation theory.[4] In the spring of 1913 he went to Columbia University to deliver six lectures on recent problems of theoretical physics and also visited Harvard and Yale universities. In addition Wien went to Washington to see Arthur Day (Kohlrausch's son–in–law), whose high–temperature measurements–with those of Wien and Holborn–had furnished the data used to confirm the energy distribution law of Wien and later Planck. While at Würzburg, Wien did not confine his attention exclusively to physics. He also studied the subjects to which his mother had introduced him–history and especially foreign literature–as well as the fine arts.

World War I affected Wien deeply, but the struggle against the "Bolsheviks, incited by literary figures (*Literaten*)" in Germany during 1918 and 1919 had an even greater impact. In 1920 he assumed his last post, at the University of Munich, where he had a new physics institute built and served as rector from 1925 to 1926. Whereas in the 1890's Wien had chosen problems arbitrarily according to their appeal to him, he took pains at Munich to select the topics first before trying them together with his students. Although satisfied with his scientific achievements, he took a gloomy view of Germany's situation in the 1920's, marked by "war tribute and socialism."[5]

Scientific Work. In his first scientific publication, when he was twenty-one, Wien demonstrated that when very bright light (whether white or colored) strikes a single metallic edge (grids failed), it is bent far into the geometric shadow of the intercepting screen. He also found that the diffracted light is polarized parallel to the edge. Further, comparison of the color formation in this type of diffraction with the absorption of the diffracting material yielded the complementary color (dissertation, Berlin, 1886). Wien perceived that the difficulties of explaining the phenomenon on the basis of the previous theories lay in their failure to take into account the oscillation of the molecules of the diffracting edge. Turning to optics, in 1888 Wien demonstrated experimentally, using the bolometer, that the dependence of the transmission of a metal on the conductance does not follow–at least in the case of silver–from Maxwell's theory of light and that the latter required further work.

Following his move to the Reichsanstalt in 1890, Wien made temperature measurements and with Holborn developed a thermoelectric temperature scale, in the form of a function of the third power of the temperature, from the "electromotive force" of the thermocouples (1892). He also extended his earlier exploration of the "flux of light" to a study of the energy of thermal radiation.[6] In 1890 and in his habilitation essay of 1892 Wien linked, very generally, J. H. Poynting's "energy flux" of electric currents with the concept of the entropy of radiation. Further, by analogy with the continuous change in position of matter in motion, he also established the motion of the energy of electrodynamic radiation, pursuing the question raised by Hertz of whether this energy can be localized at all during movement. A year later, using theoretical considerations, Wien found a characteristic of electrodynamic radiation, the displacement $\theta \cdot \lambda = \theta_0 \cdot \lambda_0$–for any wavelength λ at the same position on the *x-axis*–of any two temperature curves characterized by the different temperatures θ and θ_0;[7] he also formulated in words the constancy of the products. In this derivation Wien started from Boltzmann's finding (1884) that the expression for the electrodynamic radiation pressure could be equated with an expression for the thermodynamic radiation pressure. From this equality Boltzmann had formulated a proof of Stefan's law, which Wien completed by considering the wavelength with the aid of Doppler's principle. At the same time, as a subsidiary result, Wien determined that the individual values ø of the energy of two temperature curves are related as the ratio of the fifth power of their temperatures:

On the basis of Wien's findings, Paschen in 1896 derived the temperature independence of the expression

Wien then discovered other characteristics of the still unknown Kirchhoff energy distribution function $F(\lambda, T)$. The first was that the radiation energy disappears as wavelengths increase even within the region of finite lengths (1893); the second, that two curves for different temperatures do not intersect and that, beyond the energy maximum, they decrease no more rapidly than in proportion toλ^{-5} (1894). Both phenomena occur because of the inviolability of the second law of thermodynamics.

Starting from these regularities and others (on the whole six),[8] Wien used theoretical considerations to achieve his energy distribution law, which he published in June 1896:

where ϕ_λ is the energy at a given small interval of the abscissa and θ is the temperature. Paschen had previously communicated to Wien his experimentally derived formulation

Wien replied that he had already derived his law but that, on theoretical grounds, α: must equal 5. To support his derivation, Wien referred to W. A. Michelson's "ansatz" (1887) that the radiation function should be handled in accordance with Maxwell's statistical treatment of the velocities v. Starting from Maxwell's distribution law for the number u_v of atoms with velocity v, Wien replaced the velocity independent factor with an initially unknown function $F(\lambda)$ for v^2 on the assumption that the wavelength of radiation from molecules with velocity v is a function only of v^2. By integration and application of Stefan's law. Wien found $F(\lambda)$ to be λ^{-5}, a result that depended also on setting Maxwell's mean energy α^2 proportional to temperature. The exponent was found by the displacement law in such a manner that $v^2 = f(\lambda)$ and θ α θ Thus,in Wien's treatment, the fragment v^2 exp of Maxwell's distribution becomes

In this derivation Wien relinquished the assumption he had held since 1890 of the existence of a pure vacuum radiation, replacing it with the "hypothesis" that such radiation enters an empty space from a gas outside that space. This device, which he adopted in order to use Maxwell's gas statistics, was as much a concrete illustration and guide as was Planck's hypothesis of concrete Hertzian resonators. In 1900, and again later, physicists attacked Wien for this new interpretation of the quantities of the Maxwell distribution and, in general, for the reintroduction of gas–instead of his earlier mere cavity radiation. Nevertheless, Wien's treatment of the theory proved to be a masterstroke in the application of his well-founded suppositions of 1893–1894.

In 1897 Wien found confirmation that cathode rays were particles and of their very high velocity (about one-third the velocity of light); and in the following year he determined that they are negatively charged. Around the same time, with the help of combined electric and magnetic deflection, he also discovered the corpuscular nature, the positive charge, and the velocity (about 3.6 X 10^7 centimeters per second) of the positive rays. This new aspect of Wien's research, inspired by Lorentz' views on the electrostatic origin of gravitation, reached a logical conclusion in Wien's "Über die Möglichkeit einer elektromagnetischen Begrüundung der Mechanik" (1900). This publication constitutes the high point in the discussion of the change in size arising from the high velocity of the electrons and records the strong doubts concerning the constancy of mass.

While at Würzburg, Wien also continued his experiments with vacuum tubes. In 1905 he determined the lower boundary of the mass of the "positive electron" (called "Kanalstrahlen") as being that of the hydrogen ion. As early as 1908. following Stark's discovery of the Doppler displacement of radiation from these "electrons," Wien examined the mechanism by which they emit light; he pursued these experiments, involving the measurement of the decay time, for the rest of his life. Believing this decay to be much smaller than was supposed, Wien in 1919 devised a way of observing it in the vacuum tube that did not involve collisions: separating the space in which the positive rays are produced from the space in which they are observed. (Unlike cathode rays, they do not penetrate metal foils.) Wien allowed the positive rays to enter through a narrow slit in the vacuum tube, which he had emptied by means of the diffusion air pump recently invented by W. Gaede. (Wien used ten of these pumps.) The production space was maintained at an arbitrary, constant pressure through the gas flow method (*Durchströmungsmethode*) developed in vacuum processing. This separation technique later gained importance in the construction of elementary particle accelerators. Wien calculated the decay constant $2a$ for the decrease exp $(-2at)$ of the light intensity of the luminous particle as being approximately 5 X $10^7 s^{-1}$, which was in good agreement with the known value of the beam velocity. In 1922 Wien successfully applied his technique to the separation of arc lines (light from uncharged atoms) from spark lines (light from ions the charge of which could be shown by electrostatic deflection).

In this connection Wien in 1916 demonstrated the existence–which accords with the relativity principle–of a phenomenon that is the inverse of the Stark effect (that is, of the line splitting of a stationary light source in an electric field), experimentally showing the corresponding splitting in the case of a moving light source in a magnetic field. Also in the realm of radiation physics. Wien in 1907 sought to ascertain the lengths of Röntgen waves by measuring the impulse width. His as sumption was that these waves arise through the slowing of electrons in the electromagnetic field. In the same year, working with quantum theoretical assumptions, on which the photoelectric effect was based recently, he obtained the good value λ = 6.75 X 10^{-9} cm, five years before Max von Laue, and suggested that Röntgen wavelengths could be measured by means of crystal lattice.

In theoretical physics Wien won recognition for his conceptual experiments.[9] In his view, “such imagined processes . . . ought to correspond to realization with an unlimited degree of approximation” (1893). In 1911 Wien wrote: “Thought experiments” are devised “because for practical reasons it is often impossible to carry them out, and yet they lead to reliable results.” He maintained, however, that to posit these imagined “processes . . . the lawlike manner in which they take place . . . must be fully known,” although he granted that it is permissible to “idealize.”

In *Ziele und Methoden der theoretischen Physik* (1914), Wien distinguished mathematical from theoretical physics.[10] The former, he held, should furnish the mathematical tools–just as mathematics establishes exact relationships between numerical quantities. The latter should seek to determine quantitative laws, for which it must develop hypotheses; it can, however, attain only approximate exactness. Wien held that the laws of nature are simpler than is generally supposed by scientists, who see the infinite variety of their intricate effects. Only quantitative verification through comparison with observed data can protect the theoretician– who generally does not feel bound by experiments– from the many unsuitable ideas he generates. This quantitatively controlled interaction between theory and experiment excludes a possible carelessness in the use of mathematical expressions.

NOTES

1. For these biographical data the author is indebted to Wien’s daughter, Waltraut Wien, of Munich.

2. Wien was stimulated to record this review of his career by a letter of 17 Aug. 1927 from an unidentified American living in Denver, who solicited Wien’s response to use for pedagogical purposes. See *Aus dem Leben und Wirken eines Physikers*, 1–50.

3. Wien’s laws were assimilated so quickly into physics that when Wien went to England in 1904, people expected to see an older man instead of a “young” man of forty years of age.

4. In 1915 Wien again expressed reservations concerning Planck’s quanta; see “Theorie der Wärmestrahlung,” 217–220.

5. In 1927 Wien believed he could observe “the encroaching Americanization of all of life that is now taking place in Europe” ; see *Aus dem Leben und Wirken eines Physikers*, 74: letter to E. Schrödinger. 1 May 1927.

6. For details of this and of the following contributions by Wien to the study of thermal radiation. see H. Kangro, *Vorgeschichte des Planckschen Strahlungsgesetzes. passim.*

7. The term “displacement law” (*Verschiebungsgesetz*) was coined by Otto Lummer and Ernst Pringsheim in 1899.

8. See H. Kangro, *Vorgeschichte des Planckschen Strahlungsgesetzes*. ch. 3: 4.2: and 5.3.

9. For more on this topic. see H. Kangro, *Vorgeschichte des Planckschen Strahlungsgesetzes, passim*.

10. Wien equated theoretical physics with the English “natural philosophy” : see *Aus der Welt der Wissenschaft*, 170 Similarly, Helmholtz and G. T. Wertheim gave the title *Handbuch der theoretischen Physik* to the German translation of William Thomson and P. G. Tait’s *Natural Philosophy*.

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Like Planck, Wien gave six lectures in the United States on theoretical physics; they were published as *Vorlesungen über neuere Probleme der Theoretischen Physik, gehalten an der Columbia-Universität in New York im April* 1913 (Leipzig–Berlin, 1913); they were followed by *Ziele und Methoden der theoretischen physik* (Würzburg, 1914).(= Festrede zur Feier des 332, jährigen Bestehens der Julius-Maximilian-Universität in Würzburg am 11. März 1914), also in *Jahrbuch der Radioaktivität und Elektronik*, **12** (1915), 241–259.

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Untersuchungen über die bei der Beugung des Lichtes auftretenden Absorptionserscheinungen. Inaugural–Dissertation zur Erlangung der Doctorwürde . . . nebst beigefügten Thesen öffentlich zu verteidigen am 3. Februar 1886 (Berlin, n.d. [1886]).

On Wien's MSS, see T. S. Kuhn *et al*., eds., *Sources for the History of Quantum physics* (Philadelphia, 1967), 97a. The American Philosophical Society, Philadelphia, has some of Wien's letters to Planck; and nearly 150 letters from Planck to Wien are at the Staatsbibliothek Preussischer Kulturbesitz. The Deutsches Museum, Munich, recently acquired various other papers of Wien.

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