Max Karl Ernst Ludwig Planck

Born: 23 April 1858 in Kiel, Schleswig-Holstein, Germany
Died: 4 Oct 1947 in Göttingen, Germany

Max Planck came from an academic family, his father Julius Wilhelm Planck being Professor of Constitutional Law in the University of Kiel at the time of his birth, and both his grandfather and great-grandfather had been professors of theology at Göttingen. His mother, Emma Patzig, was his father's second wife. Both Max's parents were relatively old when he was born, his father being 41 and his mother being 37. He was born into a large family, being his father's sixth child (two of the children were from his first marriage to Mathilde Voigt), and he was brought up in a tradition which greatly respected scholarship, honesty, fairness, and generosity. The values he was given as a young child quickly became the values that he would cherish throughout his life, showing the utmost respect for the institutions of state and church.

Max began his elementary schooling in Kiel. In the spring of 1867 his family moved to Munich when his father was appointed Professor there. This city provided a stimulating environment for the young boy who enjoyed its culture, particularly the music, and loved walking and climbing in the mountains when the family took excursions to Upper Bavaria. He attended secondary school there, entering the famous Maximilian Gymnasium in May 1867. He did well at school, but not brilliantly, usually coming somewhere between third and eighth in his class. Music was perhaps his best subject and he was awarded the school prize in catechism and good conduct almost every year. One might have expected him to excel in mathematics and science, but certainly in his early school years, although he did well, there was no sign of outstanding talent in these subjects. However, towards the end of his school career, his teacher Hermann Müller raised his level of interest in physics and mathematics, and he became deeply impressed by the absolute nature of the law of conservation of energy. A school report for 1872 reads:-

Justifiably favoured by both teachers and classmates ... and despite having childish ways, he has a very clear, logical mind. Shows great promise.

In July 1874, at the age of 16, he passed his school leaving examination with distinction but, having talents for a wide variety of subjects particularly music (he played piano and organ extremely well), he still did not have a clear idea of what he should to study at university. Before he began his studies at the University of Munich he discussed the possibility of a musical career with a musician who told him that if he had to ask the question he'd better study something else.

He entered the University of Munich on 21 October 1874 and was taught physics by Philipp von Jolly and Wilhelm Beetz, and mathematics by Ludwig Seidel and Gustav Bauer. After taking mostly mathematics classes at the start of his course, he enquired about the prospects of research in physics from Philipp von Jolly, the professor of physics at Munich, and was told that physics was essentially a complete science with little prospect of further developments. Fortunately Planck decided to study physics despite the bleak future for research that was presented to him.

In [7] Planck describes why he chose physics:-

The outside world is something independent from man, something absolute, and the quest for the laws which apply to this absolute appeared to me as the most sublime scientific pursuit in life.

The off-putting comments from his physics professor clearly set the tone for his time at the University of Munich for Planck wrote later:-

I did not have the good fortune of a prominent scientist or teacher directing the specific course of my education.

He was ill during the summer term of 1875 which caused him to give up studying for a while. It was customary for German students to move between universities at this time and indeed Planck moved to study at the University of Berlin from October 1877 where his teachers included Weierstrass, Helmholtz and Kirchhoff. He later wrote that he admired Kirchhoff greatly but found him dry and monotonous as a teacher. However it is likely to be the contrast between the research attitude of his teachers at Munich and those at Berlin which prompted the quote we gave above (made many years later). One important part of his education at Berlin came, however, through independent study for at this stage he read Rudolf Clausius's articles on thermodynamics. Again the absolute nature of the second law of thermodynamics impressed him.

Planck returned to Munich and received his doctorate in July 1879 at the age of 21 with a thesis on the second law of thermodynamics entitled *On the Second Law of Mechanical Theory of Heat.* The award of the doctorate was made "summa cum laude" on 28 July 1879. Following this Planck continued to work for his habilitation which was awarded on 14 June 1880, after he had submitted his thesis on entropy and the mechanical theory of heat, and he became a Privatdozent at Munich University. Such a teaching post was unpaid so Planck received no income to support himself. He lived with his parents during the five years that he held this post, but felt rather guilty that he was continuing to live at their expense. During this time he became friends with Carl Runge and it turned into a long lasting and academically fruitful friendship.

On 2 May 1885 Planck was appointed extraordinary professor of theoretical physics in Kiel and held this chair for four years. This now made him financially secure so he could now marry Marie Merck whom he had known for many years. She was the daughter of a Munich banker, and the pair were married on 31 March 1887. He now worked on thermodynamics publishing three excellent papers on applications to physical chemistry and thermoelectricity.

After the death of Kirchhoff in October 1887, the University of Berlin looked for a world leading physicist to replace him and to become a colleague of Helmholtz. They approached Ludwig Boltzmann but he was not interested, and the same proved true for Heinrich Hertz. In 1888 the appointment of Planck was proposed by the Faculty of Philosophy at the University of Berlin, strongly recommended by Helmholtz:-

Planck's papers are very favourably distinguished from those of the majority of his colleagues in that he tries to carry through the strict consequences of thermomechanics constructively, without adding additional hypotheses, and carefully separates the secure from the doubtful ... His papers ... clearly show him to be a man of original ideas who is making his own paths [*and*] *that he has a comprehensive overview of the various areas of science.*

Planck was appointed as an extraordinary professor of theoretical physics at the University of Berlin on 29 November 1888, at the same time became director of the Institute for Theoretical Physics. He was promoted to ordinary professor on 23 May 1892 and held the chair until he retired on 1 October 1927. His colleagues and friends included Emil du Bois-Reymond (the famous physiologist and brother of Paul du Bois-Reymond), Helmholtz, Pringsheim, Wien, as well as theologians, historians, and philologists. He continued to indulge his passion for music having a harmonium built with 104 tones in each octave, and holding concerts in his own home.

While in Berlin Planck did his most brilliant work and delivered outstanding lectures. He studied thermodynamics, in particular examining the distribution of energy according to wavelength. By combining the formulas of Wien and Rayleigh, Planck announced in October 1900 a formula now known as Planck's radiation formula. Within two months Planck made a complete theoretical deduction of his formula renouncing classical physics and introducing the quanta of energy. On 14 December 1900 he presented his theoretical explanation involving quanta of energy at a meeting of the Physikalische Gesellschaft in Berlin. In doing so he had to reject his belief that the second law of thermodynamics was an absolute law of nature, and accept Boltzmann's

interpretation that it was a statistical law. In a letter written a year later Planck described proposing the theoretical interpretation of the radiation formula saying:-

... the whole procedure was an act of despair because a theoretical interpretation had to be found at any price, no matter how high that might be.

Planck received the Nobel Prize for Physics in 1918 for his achievement. He described in his Nobel Lecture given on 2 June 1920, in much more detail than we have given above, how he made his discoveries. We now give some extracts from the lecture:-

For many years, [*my aim*] *was to solve the problem of energy distribution in the normal spectrum of radiating heat. After Gustav Kirchhoff has shown that the state of the heat radiation which takes place in a cavity bounded by any emitting and absorbing material at uniform temperature is totally independent of the nature of the material, a universal function was demonstrated which was dependent only on temperature and wavelength, but not in any way on the properties of the material. The discovery of this remarkable function promised deeper insight into the connection between energy and temperature which is, in fact, the major problem in thermodynamics and so in all of molecular physics. ...*

At that time I held what would be considered today naively charming and agreeable expectations, that the laws of classical electrodynamics would, if approached in a sufficiently general manner avoiding special hypotheses, allow us to understand the most significant part of the process we would expect, and so to achieve the desired aim. ...

[*A number of different approaches*] *showed more and more clearly that an important connecting element or term, essential to completely grasp the basis of the problem, had to be missing. ...*

I was busy... from the day I [*established a new radiation formula*]*, with the task of finding a real physical interpretation of the formula, and this problem led me automatically to consider the connection between entropy and probability, that is, Boltzmann's train of ideas; eventually after some weeks of the hardest work of my life, light entered the darkness, and a new inconceivable perspective opened up before me. ...*

Because [*a constant in the radiation law*] *represents the product of energy and time ... I described it as the elementary quantum of action. ... As long as it was looked on as infinitely small ... everything was fine; but in the general case, however, a gap opened wide somewhere or other, which became more striking the weaker and faster the vibrations considered. That all efforts to bridge the chasm foundered soon left little doubt. Either the quantum of action was a fictional quantity, then the whole deduction of the radiation law was essentially an illusion representing only an empty play on formulas of no significance, or the derivation of the radiation law was based on a sound physical conception. In this case the quantum of action must play a fundamental role in physics, and here was something completely new, never heard of before, which seemed to require us to basically revise all our physical thinking, built as this was, from the time of the establishment of the infinitesimal calculus by Leibniz and Newton, on accepting the continuity of all causative connections. Experiment decided it was the second alternative.*

At first the theory met resistance but, due to the successful work of Niels Bohr in 1913 calculating positions of spectral lines using the theory, it became generally accepted. Planck himself in [7] explains how despite having invented quantum theory he did not understand it himself at first:-

I tried immediately to weld the elementary quantum of action somehow in the framework of classical theory. But in the face of all such attempts this constant showed itself to be obdurate ... My futile attempts to put the elementary quantum of action into the classical theory continued for a number of years and they cost me a great deal of effort.

Planck who was 42 years old when he made his historic quantum announcement, took only a minor part in the further development of quantum theory. This was left to Einstein with theories of light quanta, Poincaré who proved mathematically that the quanta was a necessary consequence of Planck's radiation law, Niels Bohr with his theory of the atom, Paul Dirac and others. Sadly his life was filled with tragedy in the years following his remarkable initiation of the study of quantum mechanics. His wife Marie died on 17 October 1909. They had four children; two sons Erwin and Karl, and twin daughters Margarete and Emma. Two years after the death of his first wife, Planck married again, to Marga von Hösslin the niece of Marie his first wife, on 14 March 1911. They had one child, a son Hermann. Karl, the younger of Planck's sons from his first marriage, was killed in 1916 during World War I. Both his daughters died in childbirth, Margarete in 1917 and Emma in 1919. His son Erwin became his best friend and advisor, but as we relate below Erwin died in even more terrible circumstances.

Planck always took on administrative duties, in addition to his research activities, such as Secretary of the Mathematics and Natural Science Section of the Prussian Academy of Sciences, a post he held from 1912 until 1943. He had been elected to the Academy in 1894. Planck was much involved with the German Physical Society, being treasurer and a committee member. He was chairman of the Society from 1905 to 1908 and then again from 1915 to 1916. Planck was also honoured by being elected an honorary member in 1927. Two years later an award, the Max Planck Medal, was established and Planck himself became the first recipient. He was on the committee of the Kaiser Wilhelm Gesellschaft, the main German research organisation, from 1916 and was president of the Society from 1930 until 1937 (it was renamed the Max Planck Society). This was the time that the Nazis rose to power, and he tried his best to prevent political issues to take over from scientific ones. He could not prevent the reorganisation of the Society by the Nazis and refused to accept the presidency of the reorganised Society.

He remained in Germany during World War II through what must have been times of the deepest difficulty. In 1942 he explained why he was still in Berlin:-

I've been here in Berlin at the university since 1889 *... so I'm quite an old-timer. But there really aren't any genuine old Berliners, people who were born here; in the academic word everybody moves around frequently. People go from one university to the next one, but in that sense I'm actually very sedentary. But once I arrived in Berlin, it wasn't easy to move away; for ultimately, this is the centre of all intellectual activity in the whole of Germany.*

However, being in Berlin towards the end of World War II, was very dangerous. He moved to Rogätz, near Magdeburg, in 1943. His home in the suburb of Grunewald in Berlin was destroyed by fire after an air raid in February 1944. Loosing his home and possessions was bad, but loosing his irreplaceable scientific notebooks was a tragedy for him and for science. Worse was to follow. His son Erwin was suspected of being involved in the plot to assassinate Hitler on 20 July 1944 and was executed by the Gestapo early in 1945. In [4] Heilbron describes the impact of wars on Planck and his family:-

He would remember, even in his old age, the sight of Prussian and Austrian troops marching into his native town when he was six years old. Throughout his life, war would cause him deep personal sorrow. He lost his eldest son during World War I. In World War II, his house in Berlin was burned down in an air raid. In 1945 *his other son was executed when declared guilty of complicity in a plot to kill Hitler.*

Planck was 87 years old at the end of World War II and he was taken to Göttingen by the allies. Remarkably, given his age, he was able to put effort into reconstructing German science and he again became president of the Kaiser Wilhelm Gesellschaft in 1945-1946. For the second time he defended German science through a period of exceptional difficulty.

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October 2003