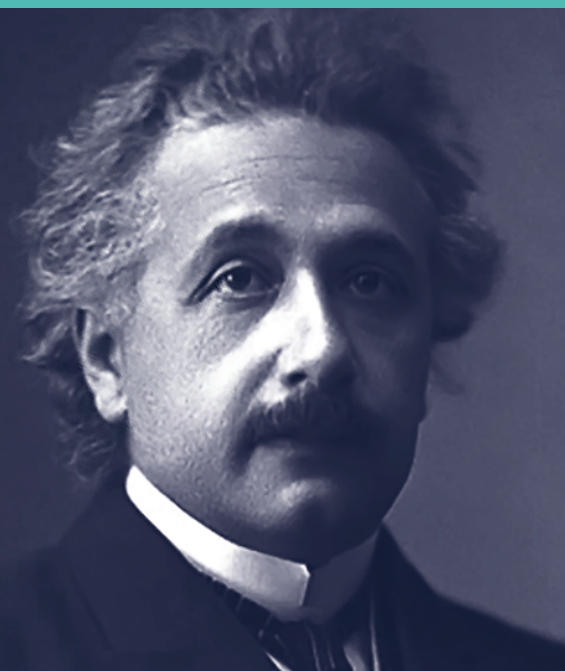


Springer Biographies



Einstein and Heisenberg

The Controversy Over
Quantum Physics

KONRAD KLEINKNECHT

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Konrad Kleinknecht

Einstein and Heisenberg

The Controversy Over Quantum Physics

 Springer

Konrad Kleinknecht
Universität München, Universität Mainz
München, Germany

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Preface

The physics of the twentieth century rests on two foundational pillars. At the beginning of the century, our place in the universe, the origin and evolution of the cosmos, and the meaning of space and time were consolidated by Albert Einstein into a new and revolutionary picture in a relativity theory described mathematically. Thereby, he predicted a great many heretofore unknown cosmic phenomena that, in the course of time, have been discovered empirically: deflection of light in a gravitational field, black holes, stretching of time in high-velocity objects, gravitational waves, and others. Shortly thereafter, in subjecting classical physics similarly to a revolutionary transformation, Werner Heisenberg was able to explain the behavior of the smallest building blocks of matter. With his quantum mechanics, he opened up for us the world of the submicroscopic constituents of matter, atoms, atomic nuclei, and elementary particles. It also permitted description of the physical attributes of molecules, chemical bonds, crystals, solid state, and semiconductors and is thus the foundation of modern computer technology. Heisenberg's discovery of the uncertainty principle has far-reaching consequences for the philosophy of nature and epistemology.

These two great scholars both grew up in Munich and attended school there, and both were lovers of music. Along with their commonalities, though, there were also significant differences in their modes of thought. Einstein held that a physical theory must predict events precisely according to the rules of causality. By contrast, from the phenomena in the atomic domain, Heisenberg concluded that a theory can only describe possible processes and their probabilities.

Einstein left us no autobiography; he felt such books were products either of narcissism or expressions of hostility toward his fellow man. So, we must

restrict ourselves in understanding his life to his correspondence and to biographies. Particularly authentic in this regard are the descriptions by his friend Philipp Frank, written in German between 1939 and 1941 in the United States. Since Einstein himself contributed a foreword to this book in 1942, it may be regarded as authorized. The Einstein estate is held at the Hebrew University in Jerusalem, and since 1987, his collected works in several volumes have been published by Princeton University Press.

Heisenberg, on the other hand, has given us a fascinating narrative of his life in his *Physics and Beyond*, which also describes his scientific breakthroughs. Additionally, two volumes of his letters to his parents and to his wife have been published. Through the agency of the Heisenberg Society, the balance of his papers has been transferred to the Archive of the Max Planck Society in Berlin; the scientific correspondence with his friend Wolfgang Pauli resides in the Pauli Archive in Geneva. His scientific papers, as well as his more generally accessible writings, are available in *The Complete Works*, published by Springer and Piper.

I wish to thank Ms. Barbara Blum-Heisenberg for providing the illustrations relevant to Werner Heisenberg and for conversations about his relation to music. Professor Hans A. Kastrup drew my attention to Albert Einstein's letter to the writer and philosopher Eric Gutkind concerning religion.

For the translation of the German book to English, I am indebted very much to Tom Artin, New York. Thanks to Maury Solomon and Hannah Kaufman for editing the book and for their ever-friendly and constructive collaboration.

München, Germany
August, 2018

Konrad Kleinknecht

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About the Author

Konrad Kleinknecht is Professor of Experimental Physics. He has done research at CERN, in Geneva; at the Universities of Heidelberg, Dortmund, Mainz, and Munich; at Caltech in Pasadena; and at the Fermi National Accelerator Laboratory near Chicago. In 1988/1989, he gave the Morris Loeb lectures at Harvard University. His work on the physics of elementary particles has been recognized by numerous prizes, among them the Gottfried Wilhelm Leibniz Prize of the DFG (German Research Foundation), the High Energy Prize of the European Physical Society, and the Stern-Gerlach Medal of the German Physical Society (DPG). In addition to research papers, he has published books on the asymmetry of matter and antimatter, on particle detectors, and on the politics of German energy policy.



1

Einstein's Youth

The Cemetery at Buchau

The Jewish cemetery of the former free imperial city of Buchau in the Duchy of Württemberg lies among tall, old trees. Since 1659, the Jews of the city and the surrounding communities of the Upper Swabia have buried their dead here. More than 800 headstones, or *mazewot*, are found here. Lettering on the oldest is weathered away. Those from the eighteenth century and later are quite legible; the most recent burial took place in 2003.

Along with the neighboring Laupheim, Buchau was one of the few free imperial cities in which from the seventeenth century onwards Jews could live, and it was socially liberal. For this reason, many Jews from the surrounding area moved to Buchau. Until 1760, the community had no synagogue. In 1828 the Jews were granted Württemberg citizenship, with all its rights and obligations. In 1838, they represented one-third of the population of ca. 2,000 people in Buchau, making it the second largest Jewish community in Württemberg.

In 1838, with financial assistance from Württemberg's King Wilhelm and Prince Maximilian of Thurn and Taxis, a new synagogue was built. It became well known throughout Germany because it was unique in possessing a bell tower patterned after neighboring Baroque churches, such as the Catholic Pilgrimage Church at Steinhausen.

The first Buchau citizen with the name Einstein was Baruch Moses Ainstein, who came to the city in 1665. At the cemetery, dozens of headstone inscriptions memorialize the 99 members of the Einstein family that are buried here.



Fig. 1.1 Headstones at the Jewish cemetery of Buchau, © Konrad Kleinknecht

The second mayor after 1946, Siegbert Einstein, a great-nephew of Albert Einstein, is also interred here.

Einstein's father, Hermann, was born in Buchau, one of seven children of Abraham and Helene Einstein. After completing school in 1869, he and his brothers moved to Ulm. He dealt in bedding feathers and later carried on this trade together with his partners Israel and Levi in Ulm. In August 1876, in Cannstatt, he married his wife, Pauline, the daughter of the grain merchant and royal Württemberg court purveyor, Julius Koch. Following their marriage, the couple moved to Bahnhofstraße in Ulm.

The Family in Ulm and Munich

Albert Einstein was born on Bahnhofstraße, in Ulm on March 14, 1879. His mother noted anxiously that the back of his head was large and angular. He did not begin to speak until he was two and a half years old. In a nursery of today, he would count as strange. Thirty-three years later, his reticence had

turned into its opposite; the physicist Max von Laue warned a colleague before his first encounter with Einstein with the words, “Watch out that Einstein doesn’t talk you to death. For he likes to do that.”

His father Hermann was of a contemplative nature, a good-hearted man who could not turn away any request, but was also not very capable in business. His mother, Pauline (née Koch), from a well-to-do family in Cannstatt, near Stuttgart, was witty, musical, and was an excellent pianist.

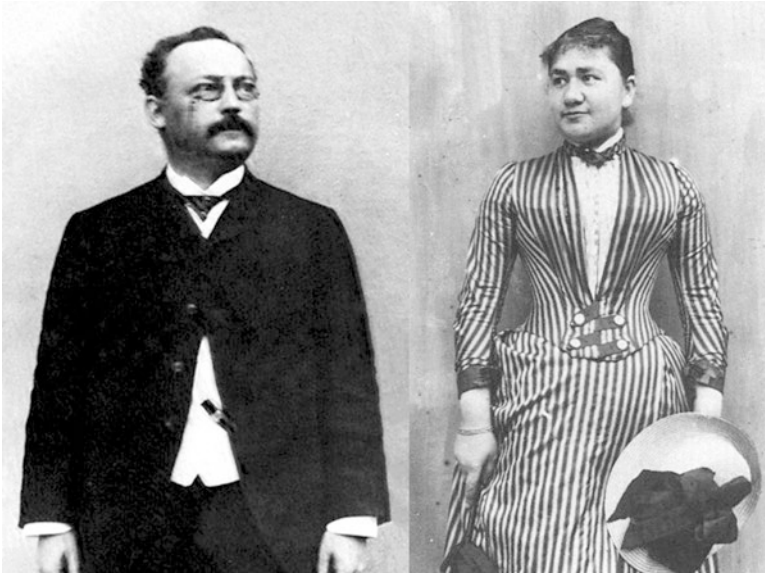


Fig. 1.2 Hermann and Pauline Einstein

In November 1881, two and a half years after Albert’s birth, his sister was born, Maria (called Maja), with whom he had a lifelong, warm relationship. Later, in a biography, she described experiences from her childhood. She noted particularly the inexhaustible patience with which her brother worked alone on his “projects.” He built palaces and castles from his Anchor Stone blocks, worked out figures from plywood with his jigsaw, and built tall, precarious buildings from playing cards. Drilling through thick boards was later one of his trademarks in physics.



Fig. 1.3 Albert Einstein with his sister Maria (Maja), 1885

Searching for special mathematical and physical gifts among Albert Einstein's relatives, one finds his Uncle Jakob (1850-1912). Hermann Einstein's younger brother had studied electrical engineering in Stuttgart at the Polytechnic Institute, and there learned the "Maxwell Equations," newly discovered by James Maxwell. They were formulated in final form in 1864. In the 1870 war, Jakob served as engineering officer. Following the war, he decided to employ his expertise to found a company in Munich for the manufacture of direct current generators and electro-motors. He designed his machines himself and had them built in the workshop.

Jakob suggested his brother Hermann join the firm and take up the position of commercial executive. Hermann agreed to the proposal and moved to Munich in 1880, at first to Müllerstraße 3, where Jakob had his apartment and his shop. The electro-technical factory J. Einstein & Co. offered the "construction of electrical power transmission plants," as well as the "construction

of electric lighting systems, fabrication of generators for lighting, power transmission, and electrolysis" and enjoyed success. The International Electricity Exhibit, organized in 1882 in the Glass Palace in Munich by Oskar von Miller, future founder of the German Technical Museum (dubbed "Deutsches Museum"), brought the new technology into the limelight. The firm Einstein & Co. exhibited their generators as well as a telephone exchange.

In 1885, the Einsteins purchased a new business site on Lindwurmstraße. They lived at Adlzreiterstraße 14, which today bears a plaque commemorating their residence. The whole extended family was gathered in this house – Hermann and Pauline, together with Albert and Maria on the second floor; Uncle Jakob, his wife Ida and Pauline's father, Julius Koch, on the ground floor. The two men and Ida ate with Albert's family, and naturally Uncle Jakob spoke about his area of expertise, electro-dynamics and its applications. Albert was probably the only 15-year-old student in Germany for whom the Maxwell equations were regular topics of meal-time conversation. In these equations the letter c , referring to the speed of light, occurs; this must have made an impression on him even then. Albert's major interest was in mathematics, in which it is possible to prove the correctness of statements oneself. A small pamphlet containing the axioms of Euclidean geometry was sacred to him. Another critical experience was his father's demonstration of a compass. The force that turned the compass needle in the northerly direction fascinated the boy. He wished to understand this mysterious phenomenon.

Initially, however, in 1885, Albert attended the Catholic St. Peter's Elementary School, where a strict regimen prevailed. He was not pleased with the drills; he disliked answering questions by rote and wished to think things through for himself. He was first in his class, and his intelligence earned him respect. As the only Jewish member of the class, he took part in the Catholic religious training, learning the biblical stories of the Old and New Testaments.



Fig. 1.4 Dwelling of the Einstein family on Adlzreiterstraße in Munich, © Konrad Kleinknecht

Student at the Luitpold-Gymnasium, Munich

In October 1888, Albert entered the Luitpold Gymnasium. Among his classmates were Robert Kaulbach, a member of the well-known family of painters, and Paul Marc, the older brother of Franz Marc. With the founding of the Blue Rider movement, Franz Marc, along with Wassily Kandinsky, became a revolutionary in painting, as was Einstein in physics. Einstein was an outstanding student at the humanistic Luitpold Gymnasium, excelling especially in mathematics.



Fig. 1.5 Gymnasium student Albert Einstein, age 14 years, in Munich

All sorts of authority were an anathema to him. He hated learning Greek and Latin vocabulary mechanically by rote. When the essence of the ancient culture was conveyed by way of the language, however, he was enthusiastic. He was most impressed by his teacher Rueß, who had the knack of presenting the ancient ideas and their influence on German culture in a lively manner. No doubt the conceptions of the Greek philosophers about nature, and their speculations about symmetries and mathematical laws, were topics of discussion that fit with Einstein's artistic nature. Accordingly, Albert always received good, even excellent, grades in the ancient languages. His teacher Rueß also taught German literature, of which Einstein's most vivid memory remained his reading of Goethe's *Hermann and Dorothea*. Schiller's dramas, too, with their idealistic heroes, had their charm for him.

Einstein's disdain for all forms of authority led to a tense relationship with several of his teachers. He felt compelled to let his teachers know his intellectual superiority. Later, during his studies at the Federal Polytechnic in Zürich, he behaved similarly. One of his professors there said to him, "You are a clever young man, Einstein, a very clever young man. But you have one great shortcoming. You don't listen to anyone else."

His skepticism regarding authority led also to the insight that, on closer scrutiny, the religious truths in the Bible "could not be consistent" with the broad context of natural science. At the Bavarian Gymnasium, religious

instruction was mandatory; there was the academic subject “Israelite Religious Education,” of which he partook. In this instance, he was not merely a disinterested auditor, as he had been in Catholic religious instruction in elementary school, but rather a regular participant. Though Einstein’s parents did not observe the traditions of Judaism, here he was introduced to the Talmud and the Old Testament, as earlier in elementary school to the New Testament. Students were naturally required to participate in religious services in the synagogue. Einstein experienced this as coercion and formalistic routine.

At the age of twelve Albert read books such as the *Popular Natural Scientific Books* by Aaron Bernstein. Reading these, he became aware of the contradiction between the biblical stories and science. He became a free-thinker. The conclusion he drew from this was that if youth is intentionally lied to in its religious instruction, then perhaps the “truths” in school books might be false as well. His suspicion of all forms of authority was thus confirmed. He even contemplated withdrawing from the Jewish religious community following gymnasium studies, although it was only later that he actually took this step.

His Uncle Jakob, who lived with the family in the same house, exercised considerable influence on Einstein. He set Albert mathematical problems, convinced that they were too difficult for the boy. Naturally, Albert solved them nevertheless. When his uncle referred to the Pythagorean theorem, the 12-year old Albert determined on finding a proof. It took him three weeks, but he stuck to it until he had found a solution.

In music, too, he applied this patient energy as soon as the substance of pieces took hold of him. Although in the early years of violin playing the technical requirements for mastery of the instrument first have to be acquired, the practices are often boring and musically unsatisfying. For this, Albert cared little. But as soon as he became aware of the great works, his interest grew, and he made an effort to acquire the technical skills for him to play his beloved Mozart violin sonatas. He retained his love of music all his life.

Meanwhile, the electrical firm J. Einstein & Co. prospered. From time to time, Albert visited the factory and thus acquainted himself with the application of the theory of electromagnetism. When he learned of a problem with production over which his Uncle Jakob had ruminated unsuccessfully for days, he quickly found the solution, much to his uncle’s delight.

With an eye to publicity, the Einsteins laid an electrical cable from their factory on the Lindwurmstraße to the Theresienwiese for the Octoberfest of 1885. The Octoberfest tents were illuminated with current from the Einstein generators together with oil lamps. Because of a fire caused by one of these lamps at the Octoberfest of 1887, in 1888 illumination of the tents was

switched entirely to electricity. The Einstein firm received the contract. The same year, the conversion from gas to electricity for the street lighting of the Munich district of Schwabing was announced, and once more the Einstein firm was awarded the contract. The new illumination was inaugurated in February 1889 to great ceremony. The celebration concluded with fireworks, rockets, and cannon fire. Jakob Einstein donated the lighting installation to the city of Munich.

At this time, the Einstein firm employed 200 workers; the family became well-to-do. But already the following year, powerful competitors came on the scene, among them Schuckert & Co., in Nürnberg, AEG, and Siemens & Halske, who all used alternating current technology. In 1892, the entire Munich street lighting system was up for grabs; all competitors submitted bids. The best offer, from Schuckert, won the contract. The bid from J. Einstein & Co. was higher by far.

In the wake of this failure, the Einstein firm had to lay off many employees; their competitors took over the lucrative commissions. In the summer of 1894, Hermann and Jakob Einstein decided to liquidate their firm and start over in Italy, where relatives of the family lived. They opened a similar firm in Pavia.

After his parents had moved to Italy, Albert remained alone in Munich, and was supposed to complete the *abitur* (secondary school exams), which were prerequisite to university study. In the fall, he entered the 7th grade (today, the 11th grade) of the gymnasium. Because he was at odds with the teacher, and the teaching methods used were unbearable to him, he was gradually confirmed in his decision to leave school. One motive could also have been that it was more difficult after the age of 16 to give up one's German or Württemberg citizenship, and thus avoid military service. From a friendly doctor, Albert got certification that he had suffered a nervous breakdown. Accordingly, a six-month's period of recuperation with his parents in Italy was medically advised. Since he knew that he would need a degree, he received from his mathematics teacher a document in writing that attested to his extraordinary abilities in mathematics that qualified him for admission to another gymnasium. His exit from the Luitpold Gymnasium was then surprisingly easy, because in December 1894 his behavior provoked quite a stir; his teacher asked Albert to leave the school because his mere presence in the class undermined respect for him. On December 29, 1894, he left the school and traveled to join his parents in Italy.