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Max von Laue

Intrepid and True: A Biography of the Physics Nobel Laureate

JOST LEMMERICH

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Intrepid and True: A Biography of the Physics Nobel Laureate

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Cover illustration: Portrait photo of Max von Laue taken in 1959 by Lotte Meitner-Graf (*Source* The author's estate)

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The von Laue coat of arms bears the inscription “Intrepid and True.” Max’s father was knighted in 1913, also granting his heirs the privilege to use the noble prefix *von* (GSta PK, Herolds Amt, I HA, rep. 176, no. 5833)

In memory of
Hans-Joachim Queisser's
"The Physics of the Twenties"
1977

Preface

One would expect that biographies of world-famous lifelong friends and colleagues would duly appreciate the bond of friendship between them. Albert Einstein (1879–1955) and Max von Laue (1879–1960) were good friends for over forty-five years. In the vast majority of Einstein biographies, this fact is not even mentioned. Any allusion to their mutual trust and solicitude tends to underrate it.[1]

No comprehensive biography of Max von Laue exists apart from the present work. Katharina Zeitz's dissertation, published in German in 2006 under the title: 'Max von Laue (1879–1960)—His Importance in the Restoration of German Science after World War II,' purposefully offers little of a biographical nature: "This treatise," she specified, "is explicitly not intended to be a biography of Max von Laue." The topics she addressed: Max von Laue's contribution toward reconstructing science after World War II; Max von Laue in Berlin—the establishment and expansion of the Fritz Haber Institute; and Max von Laue—the science organizer, are covered in the present volume only in connection with supplemental material. There are many obituaries,[2] some of them quite detailed, and one exhibition in his honor (Boeters and Lemmerich 1979). However, Laue's scientific oeuvre, the contemporary reception of it, and its significance today call for a more comprehensive biographical account.[3]

Max von Laue himself, whose father was ennobled in 1913, wrote an essay in 1944 on 'My career in physics—a self-portrayal.' The war prevented its immediate

[1] The Einstein biography by Armin Hermann (1994) refers to Laue several times, but he is not even mentioned in the one by Abraham Pais; likewise for the one by Philipp Frank. See also Cassidy 1995: 132: "As curator of the state instrument collection, Sommerfeld was also obliged to make experimental research possible, at least to a small extent—a job for assistants whom he banished to the dark cellar. Despite this subordinate status, it was there that Max von Laue and the outsiders working with him made a significant discovery. They produced evidence that X-rays behave like electromagnetic waves."

[2] Obituaries and laudatory articles on Max von Laue are by Friedrich Beck (1989: 24), Armin Hermann (1980), Peter Paul Ewald (1960), Gerhard Hildebrand (1987), Marion Kazemi (2006: 170), Walther Meissner (1960: 101), and Lise Meitner (1960: 196). An overview of the sources can be found in Henning 2004: 249.

[3] A biography of Max von Laue filling just under a hundred pages was published in Leipzig by Friedrich Herneck in 1979 but is now out of print.

appearance but he made additions to it in 1951 and the expanded version was reprinted at the head of the third volume of his collected works.[4] Such personal retrospectives generally leave many details and personal friendships unmentioned. The writings in his collected works are Max von Laue's own selection. Some of the omissions are nevertheless important to understand his development and impact as a theoretical physicist. They are therefore included in this biography.

In the present biography Max von Laue's scientific and historical publications have been taken as fully into account as possible, and their content, the messages he sought to convey, are duly assessed to show the importance he placed on clarifying the science. The correspondence and some of the publications are extensively quoted in order to give an idea of his style, his choice of words, and expression. Max von Laue's scientific publications are often very mathematical. Formal derivations could not be appropriately included in a biography such as this. Anyone interested in these important details must study the original papers.

The Max von Laue papers are deposited at various locations. The personnel files are kept at his workplaces: the former Friedrich-Wilhelms-Universität (now named Humboldt-Universität) in Berlin, Ludwig-Maximilians-Universität Munich, University of Zurich, Johann Wolfgang Goethe-Universität Frankfurt am Main, Archive of the Max Planck Society for the Advancement of Science in Berlin-Dahlem. Major portions of the extensive correspondence are held at the archives of the Goethe University in Frankfurt am Main, the Max Planck Society Berlin-Dahlem, and the Deutsches Museum. (See the key to archives and societies.)

Max von Laue was a passionate letter writer. Most are typewritten, even ones composed away from home. His handwriting is often difficult to decipher. Many letters in response have survived. Several addressees kept his correspondence and incorporated it into their estates, for example, his son Theodore, Lise Meitner, Walther Meissner, and Wilhelm Wien, who kept almost all of his letters, whereas Albert Einstein's collection is incomplete. The letters to Max Planck were apparently destroyed during the war. The incoming letters to Max von Laue including ones by Max Planck were added to the estate by the Laue family and entrusted to the archives of the Goethe University in Frankfurt am Main for safekeeping, likewise some of the family correspondence.

The scientific correspondence documents the way he thought and acted in trying to solve a given problem. Most of his textbooks, teaching material, and publications on physics and other branches of science trace the straight path to the "final" result. Laue's letters, on the other hand, relive the frustrations of dead ends, detours, and doubts that a scientist experiences.

The sheer volume of letters from people of all descriptions dictates that a selection be reached. Two multi-layered motives served as a guide: to present Max von Laue as an actor in his field and as a humanist. Important historical events in the twentieth century are briefly reviewed for the modern-day reader.

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[4] For the autobiographical manuscript, see also DMA, NL 045, "Geschrieben für Dokumente zur Morphologie, Symbolik und Geschichte" (Deutsche Denker/Geistiges Antlitz); the expanded version appeared as Laue 1944/52 and 1961, vol. 3: V–XXXIV; see also Hartmann 1952: 191.

The political environment changed five times throughout his lifetime. This always had repercussions on the further course that von Laue and his family and friends chose to follow. The quotations take this aspect into account as well. All these authentic, often spontaneously written documents form the framework of this biography. What is lacking is important supplementary indirect utterances from conversations, from dialogue. Thus, this portrait certainly cannot claim to fulfill the criteria defining that "biographical truth" which Sigmund Freud and Arnold Zweig discussed when the latter told him of his intention to write his biography. Freud's response on 31 May 1936 was: "No, I love you far too much to permit such a thing. He who becomes a biographer commits himself to lying, to secrecy, hypocrisy, glossing over, and even hiding his misinterpretations—as biographical truth is not to be had, and if it were to be had, it would be useless" (Freud 1968: 137; cf. Bruder 2003). How the following biography fares is left to the reader's own judgment.

Berlin, Germany Jost Lemmerich

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I am grateful to Christian Matthaei for granting me access to Max von Laue's estate and for providing information on the family history. Dr. habil. Michael Maaser, the director of the University Archives of the Goethe University in Frankfurt, and his staff generously supported my research. Very extensive material can be found in the archives of the Max Planck Society. Only through the help of Dr. Marion Kazemi, Dipl.-Archivar Dirk Ullmann, and Mr. Bernd Hoffmann, was it possible for me to follow up on the multifarious leads. My cordial thanks for this. I owe the selection of photographs to Susanne Uebele. In the archives of the Deutsches Museum I encountered valuable support from Dr. Wilhelm Füssl, Dr. Matthias Röschner, and Mrs. Irene Püttner. I am indebted to Dr. Vera Enke of the Archive of the Berlin-Brandenburg

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Dr. rer. nat. h.c. Jost Lemmerich
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Contents

About the Author

Dr. rer. nat. h.c. Jost Lemmerich (1929–2018) was born and died in Berlin. After earning his degree in physics at the Technical University of Berlin in 1962 as a Siemens employee, he worked on high-voltage insulation development before serving as expert in electrotechnics and control engineering at the German and European Patent Offices. His ten books include the biographies of James Franck and Michael Faraday. Annotated collections of correspondence, notably by Lise Meitner and Max von Laue, were compiled during two fellowships at Churchill College in Cambridge. He was also a gifted organizer of exhibitions in the history of science, among others on physics in the twenties, on important figures such as Einstein, Otto Hahn, Helmholtz, and Röntgen as well as on the Kaiser Wilhelm Society, the laser, microscopy, automation, thermodynamics, metrology, the ozone, quantum theory, and nuclear fission.

He was awarded the Karl Scheel Medal of the Berlin Physical Society, Germany's Distinguished Service Cross, the Justus Liebig Medal of the University of Giessen, and the Prince Bishop Johann von Egloffstein Gold Medal of the University of Würzburg.

Key to Archival Sources and Abbreviations

Key to Archival Sources

AEA	Albert Einstein Archives, Jerusalem
AMPG	Archive of the Max Planck Society, Berlin-Dahlem
APTB	Archive of the Physikalisch-Technische Bundesanstalt
BAB	Federal Archives, Berlin, Germany
BAK	Federal Archives, Koblenz, Germany
BBAW	Berlin-Brandenburg Academy of Sciences, Archive
BDC	Former Berlin Document Center, now transferred to BAB
CAC	Churchill Archives Centre, Cambridge, England
CUL	Cornell University Library, Ithaca, New York
DMA	Deutsches Museum Munich, Archive
DPGA	Deutsche Physikalische Gesellschaft, Archive
DTANL	Deutsche Akademie der Naturforscher Leopoldina, Archive
ETHZ	Swiss Federal Institute of Technology, University Library, Zurich
GNT	Center for History of Science & Technology, Univ. of Hamburg, Archive
GSta PK	Geheimes Staatsarchiv Preußischer Kulturbesitz, Berlin, now in BAB
HUA	Humboldt University Berlin, Archive
JRL	Joseph Regenstein Library, Special Collections, University of Chicago
KVA	Royal Swedish Academy of Sciences, Archives, Stockholm
LMUA	Ludwig Maximilians University Munich, Archive
NARA	US National Archives and Record Administration, Washington D.C.
NBA	Niels Bohr Archive, Copenhagen, Denmark
NL	*Nachlaß* = estate holdings, papers
PA	*Personal-Akte* = staff file
RIGBA	Royal Institution of Great Britain, Archives, London
RSA	Royal Society Archives, London
SB PK	State Library of Berlin Prussian Cultural Heritage
STAM	City archive of the Bavarian State, Munich
SUB	State and University Library of Lower Saxony, Göttingen

TNA	The National Archives, Kew, England
UAF	University Archive Frankfurt/Main
UAS	Corporate archive Axel Springer SE
UGA	University of Göttingen, Archive
UZA	University of Zurich, Archive
ZLB	Zentral- und Landesbibliothek Berlin

Societies and Professional Institutions

AVA	Aerodynamische Versuchsanstalt, Aerodynamics Design Testing Station
DPG	Deutsche Physikalische Gesellschaft, German Physical Society
FHI	Fritz Haber Institute
GDCh	Gesellschaft Deutscher Chemiker
KWG	Kaiser Wilhelm Gesellschaft
KWI	Kaiser Wilhelm Institute
MPG	Max Planck Society
MPI	Max Planck Institute
PTA/PTR	Physikalisch-Technische Anstalt/Physikalisch-Technische Reichsanstalt (Prussian/imperial bureau of standards in Berlin)
PTB	Physikalisch-Technische Bundesanstalt (German federal bureau of standards)

Journals

Ann. Phys.	Annalen der Physik
Jb. Radioakt. Electr.	Jahrbuch der Radioaktivität und der Elektronik
Nachr. Akad. Wiss. Göttingen	*Nachrichten*, communications of the Academy of Sciences Göttingen
Naturw.	Die Naturwissenschaften
Phil. Mag.	Philosophical Magazine
Phys. Bl.	Physikalische Blätter
Phys. Z.	Physikalische Zeitschrift
Sb. Math.-Phys. Kl. Bayer. Akad. Wiss.	*Sitzungsberichte*, proceedings of the mathematical and physical class of the Bavarian Academy of Sciences
Sb. Preuss. Akad. Wiss.	*Sitzungsberichte*, proceedings of the Prussian Academy of Sciences

Verh. DPG	*Verhandlungen der Deutschen Physikalischen Gesellschaft zu Berlin*, proceedings
Z. Crystall./Kristallogr.	Zeitschrift für Kristallographie (formerly Z. für Crystallographie)
Z. Physik	Zeitschrift für Physik

Chapter 1
Introduction

At the turn of the century, when Max Laue, Albert Einstein, Otto Hahn, and Lise Meitner were students, there were only speculations about how matter is structured. How might one conceive crystalline structure? A negatively charged particle had been discovered. It was called an electron and its mathematical description followed soon afterwards.[1] It appeared to be a component of atoms. But what exactly were atoms? Chemists were working successfully with a vague notion of an atom, as if they knew what it was. Robert Bunsen and Gustav Kirchhoff had jointly developed spectral analysis in 1859: each chemical element has a characteristic spectrum—but why?

Mathematics was already highly developed by then. The British physicist James Clerk Maxwell applied it to formulate the electromagnetic phenomena discovered by Michael Faraday in 1855 and to light in 1864. But was radiation actually being emitted by oscillating electrons, as several physicists were assuming?

Another open question was: What were those rays that Wilhelm Conrad Röntgen discovered in Würzburg in 1895 which penetrate through matter? Were they pulses?[2] How do the electromagnetic waves discovered by Heinrich Hertz propagate? The dispersion of light was another issue of debate. The medium that must exist for this was called the "aether". It was neither visible nor could it be analysed. Does it envelope Earth, does it move along with it?

As a rule, basic research in the German Empire was being conducted at its twenty-one universities. In 1886/87 nine of them were employing over a hundred lecturers each. In Berlin, the Friedrich-Wilhelms-Universität, founded in 1810, engaged 288 faculty members to teach 5766 students, followed by the Ludwig-Maximilians-Universität in Munich with 158 lecturers and 3060 students.

The Göttingen mathematician Felix Klein and the expert at the Prussian Ministry of Culture, Friedrich Althoff, introduced a system of priority research for some universities (Sachse 1928: 234, 277; Brocke 1987: 195). Göttingen was assigned

[1] Abraham (1903). On the importance of the *Annalen der Physik*, see Pyenson (1985): 195.

[2] On the question of what exactly radiation might be, see Hentschel (2007): 172, 283, 443, 525.

J. Lemmerich, *Max von Laue*, Springer Biographies,
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mathematics as its main focus. Students were largely given free rein in determining which courses to take. They only had to pass final oral examinations in defense of a submitted written thesis. The natural sciences, including physics, generally belonged to the Faculty of Philosophy. Therefore, an examination in philosophy was compulsory. This external framework defined the path that Max Laue was to follow in academia.

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Chapter 2
Childhood and Youth

Max Theodor Felix Laue was born on 9 October 1879 in Pfaffendorf (district of Coblenz) in the German Empire. Prussia was one of the four kingdoms in the German Kaiserreich, founded in 1871 after the victorious war against France. The military played an important and respected role in Prussia and the new state. Max Laue's father, Carl Julius Laue (1848–1927), was a military intendant assessor and ranking lieutenant when his son was born. He had fought in the campaign of 1870/71, initially as a noncommissioned officer, then as vice-sergeant, before being promoted to lieutenant of the Landwehr and awarded the Iron Cross 2nd Class.[1]

The large fortress Ehrenbreitenstein looms above Coblenz across the river (Fig. 2.1). Carl Julius Laue was probably stationed there and performed his service at the fortress. He and his brother and two sisters originally came from the Magdeburg area. In 1878 he married Minna, née Zerrenner, the daughter of a local merchant there. His father Theodor owned three distilleries. Carl Julius had met Minna in Magdeburg while doing service there in 1868/69.[2]

[1] On the father's military career, see GSta PK, Königl. Heroldsamt, I. HA, rep. 176, no. 5833, fol. 6; Lemmerich (2011): 155.

[2] Lemmerich (2011): 282. Max von Laue wrote in a letter about his mother: "Now she began to speak about her engagement to a rich young merchant who had showered her with attentions, but unfortunately died before the wedding could take place. She didn't tell me his family name. His given name is like mine. Since, she named her son after him".

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Fig. 2.1 Old Coblenz can be seen on the left, Pfaffendorf, Max von Laue's birthplace, is in the foreground, Ehrenbreitenstein Fortress is on the right. *Source* The author's estate

His son Max, born a year later, probably attended elementary school in Pfaffendorf.[3] But soon the family had to leave because in the military it was customary to change location upon promotion. Meanwhile Minna had given birth to their daughter Elizabeth. Traveling through Brandenburg along the river Havel and by Altona, the young family arrived in Posen (currently known as Poznan in Poland) in 1888, the fortified capital of the Prussian province of the same name. Carl Julius Laue was promoted to captain. Ten-year-old Max attended grammar school there at Friedrich-Wilhelms-Gymnasium. Occasional excursions were made back to the parental home turf and once to the Devil's Wall in the Harz Mountains.[4] As a *Tertianer* pupil in the fourth or fifth grade there, Max had to change schools again when his family relocated to Berlin. His most memorable classroom experience was at the Wilhelms-Gymnasium when he learned about the separation of copper metal from a copper sulphate solution. He recollected in his autobiography:

> The impression that this first contact with physics made was tremendous. For a few days afterwards I wandered about idly lost in thought, causing my mother to ask me anxiously what was wrong with me. When she got to the bottom of it, she saw to it that I often visit the 'Urania' on Taubenstraße, a popular science society where physical apparatus stood ready

[3] Max Laue had to fill out forms about himself several times during his academic career, among others for membership into an academy. They differ somewhat, for example, his application for admission to the Akademie Deutscher Naturforscher Leopoldina in Halle (Archive, Max Laue file) and the form in his personnel file at the Humboldt University Archive (HUA, UKP, L51). The present biography uses the most likely figures.

[4] Excursion by car 1–6 Mar. 1932 with his son Theodore. AMPG, III rep. 50, suppl. 1, car touring book [unpaginated, unchronological].

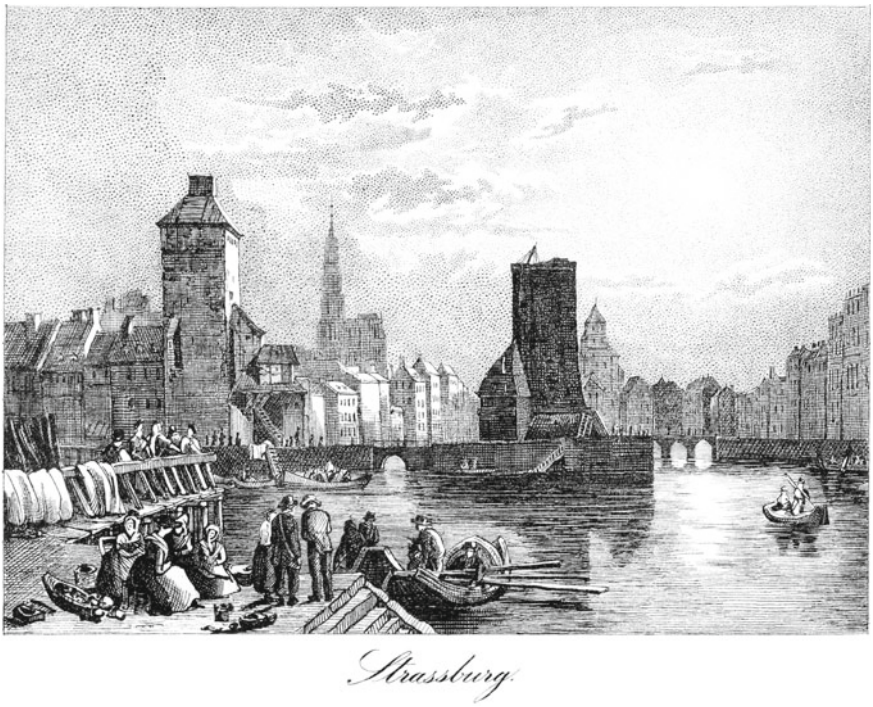

Fig. 2.2 View of Strasbourg. To secure the city militarily, a total of 14 forts were built in 1872. This made it one of the most heavily armed locations of the German Empire. *Source* The author's estate

> in large numbers to demonstrate simple experiments; reading the given instructions, one just had to press a button and then watch the informative process take place.[5]

But soon the family had to move away again to Strasbourg, which Louis XIV had annexed in 1682 and transformed into an anti-German stronghold. The victorious campaign of 1870/71 had reunited Strasbourg with the German Empire.

Strasbourg was a larger city counting just over 100,000 residents, 9485 of whom were attached to the military. The Protestant population outnumbered the Catholics. The city had suffered much destruction during the war of 1870–71, and the Reich had invested heavily in restoring it. The construction of a university building was part of that policy (Fig. 2.2).

The family lived in spacious official accommodations near All Saints' Abbey. Laue's father wanted his son to continue his education in a cadet school with suitable training in subordination, but his mother succeeded in dissuading her husband. In 1893 Max joined the Tertianer class at the famous Protestant Gymnasium, a grammar school for boys only, as was normally the case at the time. In his memoirs

[5] Laue (1961), vol. 3: V; also DMA, NL 045 and Hartmann (1952): VI. Laue attended lectures at the Urania as well.

Max Laue devoted a lengthier section to this period and his teachers. He praised the "extremely kindhearted director, H. Veil […], who knew that each individuality has a right to develop itself according to its own law, who, himself an enthusiastic classical philologist with a strong theological bent, acknowledged the legitimacy of mathematics and the natural sciences and defended me on more than one occasion against other teachers when they took offence at my mathematical and physical inclinations, as sometimes happened."[6] He also warmly remembered his teacher of classical languages and religion, Erdmann, quoting his motto: "Anyone in enthusiastic pursuit of a great cause can't go completely astray." Laue himself agreed: "My life goes to show for it (ibid.)." The mathematics and physics teacher, Professor Göhring, was also deemed worthy of mention, not only for his manner of stimulating scientific thinking but also for his advice to read the 'Popular Lectures on Scientific Subjects' by Hermann von Helmholtz (1875), which kindled Laue's lifelong admiration for the author.[7] In the two final years of school he and two of his school friends[8] sharing similar scientific inclinations performed all kinds of experiments with greater or lesser success, including generating X-rays. They studied Adolf Wüllner's textbook (1862) on experimental physics[9] and educated themselves independently in mathematics to the point of trying their hands at differential and integral calculus. Max became the best pupil in the subject. Hiking and bicycle tours[10] with his friends in the vicinity of Strasbourg deepened Laue's interest in the countryside and in the animal kingdom awakened early by a gift from his maternal grandfather, a copy of Brehm's *Animal Life* (1890).

In March 1898 Laue passed his school leaving exams, but only earned top marks ("sehr gut") in mathematics and physics. By then he had reached the age for completing his compulsory military service, which bothered him because he did not like the rifle drills, "*Griffeklopfen*"[11] as he called them (Fig. 2.3). He was also very critical of the way that recruits were treated. He abhorred militaristic comportment and unquestioning obedience throughout his life, as many letters prove.

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[6] Laue to Theodore, Berlin, 5 Aug. 1954. AMPG, III rep. 50 suppl. 7/14 (car touring book), fol. 31. Laue provides two spellings for this name: Veil or Weil.

[7] Unfinished address by Laue at the Academy, in Göber and Herneck (1960).

[8] Fecht to Laue, 7 Apr. 1954. UAF, Laue papers, 3.3. Hermann Fecht, one of Laue's school friends, nicknamed him "Lehe."

[9] Adolf Wüllner was a professor at the Technical University of Aachen.

[10] Laue to Meitner, no loc., 29 Sep. 1943. Lemmerich (1998): 310; see also: AMPG, III rep. 50 suppl. 1, car touring book: "In August of this year I could have celebrated my 50th bicycle-riding anniversary. […] I got a bicycle. It still had solid tires." When the Laues took a road trip to the Black Forest in June 1933, Laue recalled cycling in the area as a schoolboy. He had relatives on his father's side in Offenburg.

[11] Laue is mentioned frequently in the Einstein correspondence. This allusion appears in Einstein to Zangger, 11 Jan. 1915, Schulmann (2012).

Fig. 2.3 Max Laue in uniform, Strasbourg 1898/99. *Source* Bildagentur bpk, No. 10024545, G. Michel

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Chapter 3
Studies in Physics

Still on active military duty, Laue was granted permission to study at the Imperial University in Strasbourg. The French university had been dissolved in 1871 to make room for the new Kaiser Wilhelm University. Laue was matriculated on 19 October 1898. According to the student register, from the winter semester of 1898 until the end of the summer semester of 1899 he attended the courses Experimental Physics II taught by Ferdinand Braun, Potential Theory by Reye, Defined Integrals by Krazer, Analytical Geometry of Space, Descriptive Geometry, Exercises in Geometry, and Physical Exercises by Braun, General Experimental Chemistry by Fittig, and Ethics by Ziegler (UAF, Laue papers, 1.10).

At 45 years of age, Ferdinand Braun had been lecturing at Strasbourg as full professor since 1895 (Kurylo and Süsskind 1981). His career had led him there from a teaching position at a high school. It was during this period that he discovered the rectifier effect while analysing crystals. Working with discharge tubes inspired by the discovery of X-rays in 1895, he had succeeded in inventing a display method for electrical processes by means of his device which came to be known as the 'Braun tube.' After the young Italian Guglielmo Marconi had demonstrated the applicability of Hertzian waves in communications technology, Braun began very successful high-frequency investigations in 1898, supported by his assistant Jonathan Zenneck,[1] who also held the practical course for beginners. Laue attended these stimulating lectures in uniform and watched the brilliant experimental demonstrations by Ferdinand Braun. Unlike many theoretical physicists of his day, Max Laue always appreciated experimental research and Braun's lectures may have been one of the reasons for it.

[1] Jonathan Zenneck (1871–1954) liked to tell the story that his parents, in wise premonition, had given him the names—Jonathan Adolf Wilhelm—so that he would always be well equipped with the right first name for each of the three political eras in Germany. He was an active promoter of the Deutsches Museum in Munich and was often in contact with Max von Laue, see Lemmerich 2011: 204.

J. Lemmerich, *Max von Laue*, Springer Biographies,
https://doi.org/10.1007/978-3-030-94699-9_3

Around Christmastime in 1898, his mother was definitively diagnosed as suffering from cancer. An attempt was made to save her life by surgery, but it came too late. Decades later, Laue wrote about this to his son Theodore:

> At the beginning of March she asked Father Steinwedel, who had confirmed Elly and me, to give her and all of us Holy Communion. Then her strength rapidly drained away. On the 19th I was sitting alone at her bedside and at her request was giving her some water in a teaspoon. And as I was about to do so again, a slight shudder ran through her body and her sufferings were over. I closed her eyes soon afterwards. My father entered the room only later. She was then laid out in the large livingroom of our apartment. The military had granted me 3 days' leave (but I still had to take part in a shooting exercise), and then I sat by her bier until she was brought away to the freight depot accompanied by a long, solemn train 2 or 3 days later. She was buried in Magdeburg at a later time. My father had forbidden me from also taking part in that ceremony (Lemmerich 2011: 282).

Max became estranged from his father, who remarried a few years later and was living in Berlin. It is not known why no enduring bond developed between Max and his younger sister.

In the autumn of 1899 Laue continued his academic studies at the University of Göttingen. He was registered as "stud. Math.," matriculation no. 387. A physics student by the name of Paul Kirchberger became a good friend of his.[2] At Göttingen Laue was able to attend lectures by eminent scientists. He took part in practical sessions in chemistry and physics as well.

The focus on mathematics at Göttingen attracted extraordinarily brilliant faculty, foremost Felix Klein, David Hilbert (Fig. 3.1) and, from 1902 on, Hermann Minkowski. In his self-portrayal 'My career in physics' Laue wrote about Hilbert:

> This man figures in my memory as perhaps the greatest genius I have ever set eyes upon. […]
>
> Mathematics conveys the experience of Truth most purely and directly; its essentiality in basic human education rests on this. And a beautiful, intrinsically consistent mathematical proof was one of my greatest joys already at school (Hartmann 1952: XV, Laue 1961).

Carl Runge, a notable representative of applied mathematics born in 1866, joined its ranks in 1904. His family home became a favorite meeting place among the younger generation of scholars. Woldemar Voigt held the chair in physics. He had been studying the fundamental physical properties of crystals since the turn of the century. How much this subject featured in his lectures is not known, but Laue was impressed enough by the way that Voigt presented the material to decide to dedicate himself definitively to theoretical physics. Other academic teachers at included Max Abraham, Ernst Zermelo and Walther Nernst. But for Laue as a student, course attendance was much less significant than his readings. The scientific literature took up the majority of his time. His textbooks probably included Gustav Robert Kirchhoff's 'Lectures on Mathematical Physics', 'Emission and Absorption' as well as the 'Treatises on Mechanical Heat Theory.' In his memoirs he mentions studying

[2] Laue (1961) vol. 3: V; UAF, Laue papers, 1.10. Paul Kirchberger also authored two books (1920, 1922). As a target of the Nazi racial laws he committed suicide in 1938, see Lemmerich (1998): 204.

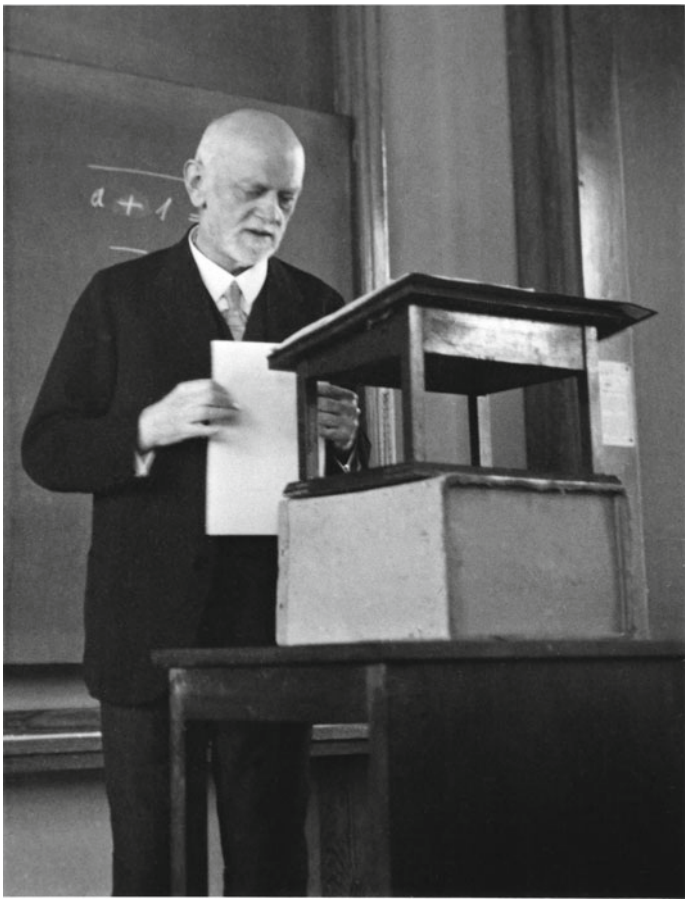

Fig. 3.1 The mathematician David Hilbert (1862–1943) at a lecture in 1932. *Source* Photograph in the author's estate

the equations found by the Scot James Clerk Maxwell on the correlation between electricity and magnetism, which Maxwell had formulated on the basis of Michael Faraday's experiments on induction. About these Maxwell equations, Laue quoted the Austrian physicist Ludwig Boltzmann's exclamation:

> Was it a god who wrote these signs, appeasing my inner turmoil, revealing Nature's forces all around me? (UAF, Laue papers, 1.10).

Max Laue refused to join any student fraternity that was still practising the dueling tradition. Many students chose to study in Munich during the winter term in order to be near the ski slopes in the mountains. In this rite Laue was willing to partake, although as a novice he had to settle for hiking. It was only in 1906 that he truly began to enjoy skiing as a sport. Table 3.1 lists the courses he attended in Munich.