Chapter 3
Max Planck as Textbook Author

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3.1 Planck and Thermodynamics

Not only is Max Planck regarded as one of the outstanding theoretical physicists of his age, who helped establish the field of modern physics with his quantum hypothesis, he was also the author of a five-volume series of textbooks called *Einführung in die theoretische Physik* (1919), which makes him one of the discipline's classic textbook authors. This series emerged from Planck's lectures at the University of Berlin, and the textbook became a standard work on physics the world over. It played a role in contemporary physics training—at least in the interwar period in German-speaking countries—similar to that of the textbook series by Lev Landau and Evgeny Lifshitz, or the "Lectures" series by Richard Feynman. Thus it can be considered a textbook in the traditional sense, and all but the ideal in its fulfillment of a textbook's function, as defined so concisely by Thomas S. Kuhn in *The Structure of Scientific Revolutions*, to "expound the body of accepted theory, illustrate many or all of its successful applications, and compare these applications with exemplary observations and experiments" (Kuhn 1970, 10).

But the story of Planck as a textbook author had already begun decades before this series. In 1897 the publishing house Veit & Company in Leipzig released Planck's one-volume *Vorlesungen über Thermodynamik*. According to Planck, the book originated from suggestions by his colleagues and students that the "treatises [by Planck] that cover the area of thermodynamics be published as a collection or edited into a summary" (Planck 1897, iii). Yet, as Planck explains in his preface, he decided not to follow this advice. Instead he wanted to rid the texts of their character as research results and lend them more of the nature of a textbook

> intended as an introduction to the study of thermodynamics for anyone who has completed a course in beginning physics and chemistry and is familiar with the elements of differential and integral calculus. (Planck 1897, iii)

In this way he could "develop in greater detail some of those general considerations and proofs that were kept a bit short in the terse style of tracts, in order to make them more understandable," and also "expand on the corresponding subject in order to summarize the entire area of thermodynamics in a coherent presentation" (Planck 1897, iii). Despite his best intentions, it must be admitted that the origin of the text in Planck's lectures can still be detected, and in such a way that the book differs considerably from what we accept as a textbook today.

The individual lectures are divided into four sections. In the first section there are three subsections dealing with "basic facts and definitions" like temperature, molecular weight,

and thermal energy; the second section covers the first law of thermodynamics, including not only its general formulation, but also its application to homogeneous and inhomogeneous systems; the third section discusses the second law in a similar manner; the subject of the fourth and final section is "applications to special equilibria," which range from homogeneous systems, to systems in various aggregate states, all the way down to dilute solutions.

Although Planck had offered regular courses on thermodynamics and the mechanical theory of heat ever since his stint as a private lecturer in Munich, and in spite of the fact that the title of the book, as well as the purpose Planck claimed in its preface, suggested the character of a textbook, the lectures on thermodynamics published in 1897 resembled less elaborated lessons than an account of Planck's own thermodynamic studies. He attempted a retrospective sketch of these studies in his autobiography of 1947:

> [After] my doctoral dissertation at the University Munich, which I completed in 1879 [I continued] my studies of entropy, which I regarded as, next to energy, the most important property of physical systems. Since its maximum value indicates a state of equilibrium, all the laws of physical and chemical equilibrium follow from a knowledge of entropy. I worked this out in detail during the following years, in a number of different researches. First, in investigations on the changes in physical state, presented in my probationary paper at Munich in 1880, and later in studies on gas mixtures. All my investigations yielded fruitful results. (Planck 1949, 18–20)

These basic experiments on thermodynamic equilibria in physico-chemical systems, which were also the focus of Planck's lectures, came to a provisional conclusion in the mid–1890s. In the following years, Planck then concentrated on radiation equilibria; hence the publication date of his lectures was anything but coincidental. It can be considered a kind of summary of his early work on thermodynamics. On this basis, and because didactic principles play practically no role in its impartation of the latest thermodynamic knowledge, the *Vorlesungen* seem to be more of an encapsulating portrayal and synopsis of contemporary thermodynamic knowledge than a standard textbook. What is interesting is that Planck's *Vorlesungen über Thermodynamik* was reissued and expanded repeatedly—up to the ninth edition in 1930, under the aegis of their original author, and then in its tenth (1954) and eleventh (1963) editions, edited by Max von Laue and Max Päsler, respectively. Meaning these lectures were republished more often than any other book by Planck, which probably reflects less his virtues as a textbook author and more the importance and standing of his works on thermodynamics, which distinguish him as one of the leading thermodynamicists of all time (Ebeling and Hoffmann 2008, vii–xxiv).

3.2 Heat Radiation

As a first-rate expert on thermodynamics, Planck had the means at his disposal to resolve the contradictions prevalent within the theory of radiation at the end of the nineteenth century, contradictions which neither the tools of electrodynamics nor those of optics could resolve. This becomes abundantly clear in Planck's second textbook, his *Theorie der Wärmestrahlung*, subtitled *Vorlesungen von Max Planck*, which was published by Johann Ambrosius Barth's publishing house in Leipzig in spring 1906. According to the preface, the "main

contents" of these lectures reflect "the lectures [Planck] held at the University of Berlin in winter semester 1905/06" (Planck 1906, iv). Even though the structure of the book exhibits many similarities to Planck's *Vorlesungen über Thermodynamik*, the lectures on the theory of heat radiation certainly read more like a textbook. Compared to his earlier text on thermodynamics, Planck's work on heat radiation is less focused on his own research, and in addition, it discusses the subject much more comprehensively—in the manner of an "introduction to the study of the entire theory of radiative heat on a uniform thermodynamic foundation" (Planck 1906, iii). With this text Planck provided what has come to be recognized as the first comprehensive account of the theory of radiation.

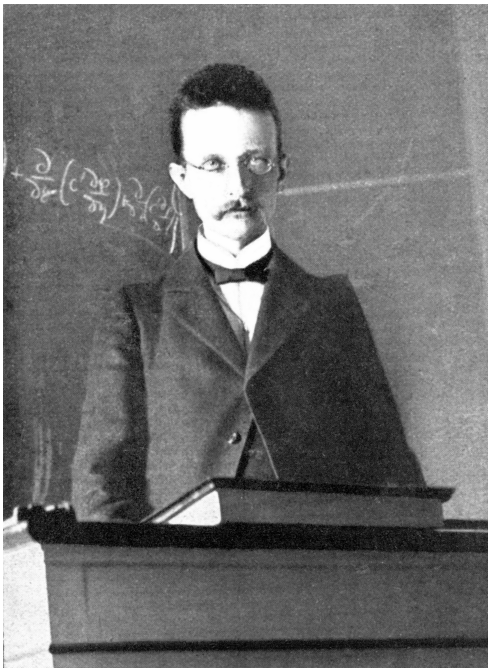

Figure 3.1: Max Planck teaching, late1880s. Archive of the Max Planck Society, Berlin.

The book opens with explanations of the basic principles of (geometric) optics required for the study of heat radiation, especially the laws for the propagation of radiation and the (classical) electrodynamic laws for the emission and absorption of radiation. Then the basic laws of heat radiation are explained: Kirchhoff's radiation law, black-body radiation, the Stefan-Boltzmann law and Wien's displacement law, all generalized so as to apply to radiation with any spectral energy distribution. A whole section is devoted to discussing the linear oscillator as the (simplest) model for emitting and absorbing systems. The central, fourth section of the book investigates the interrelation between entropy and probability, deriving the energy distribution of black-body radiation from a statistical treatment of radiating oscillators, thereby enabling Planck to deduce a universally valid radiation formula. In this statistical treatment Planck's constant h, the quantum of action, appears as a new, universal

natural constant, and Planck's law is derived. The book's final section is then devoted to irreversible radiation processes.

Planck's *Vorlesungen über die Theorie der Wärmestrahlung* was a success and carved out a prominent position among contemporary physics textbooks. Indeed, the success of the lectures was probably why the S. Hirzel-Verlag of Leipzig approached physicist and author Arnold Sommerfeld of Munich with a proposal to collaborate with Planck in developing a textbook on theoretical physics (Sommerfeld 2000, vol. 1, 354–368).[1] At the time, these two men were considered to be *the* authoritative representatives of theoretical physics in Germany; they were both also known for giving outstanding lectures. This idea was not realized, however, and at least one reason why can be gleaned from the surviving correspondence; Sommerfeld asserted, "that the consistency of such a work, which is supposed to be its major advantage, is better ensured when a single author does the whole thing"[2] (Sommerfeld 2000, vol. 1, 354–368). Certainly both authors were also aware that their approaches to such a textbook would differ considerably. Planck took great pains to adhere to a systematic, logical structure in his textbooks, and presented the material in a more deductive way, whereas Sommerfeld placed the concrete problems of physics in the foreground, which is particularly and strikingly clear in the textbook he published a decade later, *Atomic Structure and Spectral Lines* (cf. the chapter by Michael Eckert in this volume). In the preface to the first volume of his *Vorlesungen über theoretische Physik*, Sommerfeld himself elaborated on the differences between the two textbooks:

> Compared with the lectures by PLANCK, which are flawless in their systematic structure, I believe that what argues in favor of my lectures are their greater richness of material and freer treatment of the mathematical apparatus. Yet I gladly refer, especially as concerns thermodynamics and statistics, to the more comprehensive and in many ways more thorough account by PLANCK.[3] (Sommerfeld 1943a, vi)

It also speaks to the success of Planck's *Vorlesungen über die Theorie der Wärmestrahlung* that the book ran through six editions—five during Planck's lifetime. The last edition to date was issued by the physicist Hans Falkenhagen of Rostock in 1966, as a reprint of the fifth edition from 1923. The 1966 edition was presumably a response not so much to contemporary teaching needs as the historical interests of the publisher and the physical community of the day; the East German publisher certainly hoped that the distribution of the reprint in the West might also bring in hard currency.

The individual editions differ from each other, sometimes significantly, not least of all because they mirror the development of quantum theory. The greatest differences are found between the first edition (1906) and the second (1912). As Planck explains in his preface to the second edition, the years between 1906 and 1912, considered with respect to the "special theory outlined in this book, especially the hypothesis of the elementary

[1] Hirzel to Sommerfeld, February 1909; Planck to Sommerfeld, February 1909.

[2] "daß die Einheitlichkeit eines solchen Werkes, die ja gerade sein Hauptvorzug sein soll, besser verbürgt ist, wenn ein Einziger das Ganze macht." All English translations by the author.

[3] "Gegenüber den Vorlesungen von PLANCK, die im systematischen Aufbau einwandfrei sind, glaube ich zu Gunsten meiner Vorlesungen eine größere Reichhaltigkeit an Stoff und eine freiere Handhabung des mathematischen Apparats anführen zu können. Ich verweise aber gern, insbesondere was Thermodynamik und Statistik betrifft, auf die vollständigere und vielfach gründlichere Darstellung von PLANCK."

quantum of action, were by and large beneficial. In particular my radiation formula has proven satisfactory so far"[4] (Planck 1912, iv). In addition, during these years, not only did Planck's law find convincing experimental confirmation, but also, and more importantly, the quantum hypothesis was applied successfully by physicists like Albert Einstein, Walther Nernst, Peter Debye, and Johannes Stark—to name but a few—to resolve other, until then intractable physical problems that fell outside the sphere of radiation theory (Hermann 1971). The Solvay Conference of October 1911, whose prominent participants included Planck, had, after all, made clear once and for all with the authority of the leading contemporary physicists that the "quantum problem" was not a special problem for radiation theory, but rather a question fundamental to the development of contemporary physics.

Against the backdrop of contemporary developments in quantum theory, Planck reworked his textbook significantly—for instance, by completely eliminating the section *Emission und Absorption elektromagnetischer Wellen durch einen linearen Oszillator*, which discussed in great detail the oscillator model. In this instance, Planck was reacting to the consequences of the quantum hypothesis placing limits on the validity of the classical laws of electrodynamics; furthermore, the oscillator model turned out to be an oversimplification. Instead, the quantum hypothesis itself, and the assumption of finite energy elements, were more clearly made the focus, in that the leitmotif guiding his reworking of the lectures was to "connect the quantum hypothesis as closely as possible to classical dynamics, and to penetrate the barriers of the latter only where the facts of experience leave no other alternative"[5] (Planck 1912, vi). Characteristic of this conservative approach, Planck presents in the book his second quantum theory, which he had only developed in 1911/12. The new theory presupposes a discontinuous and quantal emission process for radiation, whereas absorption, as before, takes place continuously, in accordance with the classical electrodynamics per Maxwell's equations (Planck 1912, 150–160). The developing quantum theory was quick to gloss over such attempts at a classical reinterpretation of the initial quantum hypothesis; remarks in this vein had disappeared by the fourth and fifth editions of 1921 and 1923, respectively. Instead Planck took into account the latest developments in quantum theory, from the Nernst heat theorem and the application of the quantum hypothesis to the temperature dependence of the specific heats of solids, to the Bohr model of the atom, and all the way to the Stern-Gerlach experiment—albeit presented in all brevity, which certainly must have posed a challenge to the students and readers attempting to understand the material.

The fact that there were no new editions after the fifth edition of 1923—aside from the aforementioned sixth edition of 1966, which should be regarded as a historical reprint rather than a textbook—can be explained primarily by the progressive shift in the focus of quantum theory, ever further away from radiation theory, and ever more toward the problems of atomic and electron theory, which began with the acceptance of Bohr's atomic theory at the latest, and marginalized Planck's thermodynamic approach, transforming heat radiation theory into a peripheral special case.

[4] "in diesem Buche entworfenen speziellen Theorie, insbesondere der Hypothese des elementaren Wirkungsquantums, im großen und ganzen günstig gewesen. Vor allem hat sich meine Strahlungsformel bisher befriedigend bewährt."

[5] "den Anschluß der Quantenhypothese an die klassische Dynamik so eng als möglich zu gestalten, und die Schranken der letzteren erst da zu durchbrechen, wo die Tatsachen der Erfahrung keinen anderen Ausweg mehr übrig lassen."

3.3 The *Introduction to Theoretical Physics*

It may also have played a role in the demise of the textbook that, in the meantime, the same publisher had issued Planck's multi-volume *Einführung in die theoretische Physik*. The second part of the final, fifth volume of this new textbook, which appeared in 1930, is devoted almost entirely to the topics of heat radiation and quantum theory. For reasons of space, more general and synoptic considerations are naturally foregrounded, and concrete applications almost completely eliminated. Hence the contents of the *Vorlesungen über die Theorie der Wärmestrahlung* are by no means fully incorporated in Planck's new volume on the *Theorie der Wärme*; on the contrary—as Planck states himself—"in a sense [they] complement each other reciprocally"[6] (Planck 1932, v).

Planck's *Einführung in die Theorie der Wärme* of 1930 concluded a textbook project that he had begun in 1919. Reference was made above to the context of Planck's lectures and to the S. Hirzel Verlag's idea of publishing a textbook written jointly by Planck and Sommerfeld. In the subsequent years Planck apparently completed the textbook project by himself, and, in the process, initially discouraged Sommerfeld from writing a similar book (cf. the chapter by Michael Eckert in this volume); however, this may also be what prompted Sommerfeld to concentrate fully on writing his epochal *Atomic Structure and Spectral Lines*. As he admitted to Hirzel in June 1924, he had

> often thought about publishing my lectures, but now that Planck's lectures are appearing in your publishing house, I do not consider this urgent. The effort is much greater than you think.[7] (Sommerfeld 2000, vol. 2, 164)

Hence, Sommerfeld's six volumes of lectures on theoretical physics did not appear until the 1940s.

Like the other textbooks by Planck discussed above, his *Einführung in die theoretische Physik* emerged from his lectures at the University of Berlin. He had begun these lectures upon his appointment in the summer semester of 1889, and they were conceived as a five-semester course encompassing the classical areas of theoretical physics—from mechanics to optics—and providing a comprehensive introduction to the field. Interestingly, he modified the sequence of the lectures, closing them not with electricity and optics, which had been customary up to that time, but with the theory of heat. As he writes in his preface to the *Theorie der Wärme*, "[this] was imperative to the functional systematization to which I aspired. For while the theory of heat may build on mechanics and electrodynamics, this is not true the other way around"[8] (Planck 1930, v). This emphasizes, once again, the central role of thermodynamics in Planck's physical thinking. Incidentally, authors of later textbooks would follow Planck in this systematization (Sommerfeld 1943b; Joos 1932).

[6] "ergänzen sie sich in gewissem Sinne wechselseitig."
[7] Sommerfeld to Hirzel, 30 June 1924.
[8] "war [dies] ein zwingendes Gebot der erstrebten sachlichen Systematik. Denn wohl lässt sich die Theorie der Wärme auf der Mechanik und auf der Elektrodynamik aufbauen, nicht aber gilt das umgekehrte."

Figure 3.2: Advertisement by the publishing house for Planck's textbook *Einführung in die theoretische Physik* (Planck 1932).

Planck's *Einführung in die theoretische Physik*, several editions of which were published in the interwar period, but which was never republished after World War II, is divided into the following volumes:

- Volume 1: *Einführung in die allgemeine Mechanik* (Introduction to general mechanics); 1st edition 1916; 2nd edition 1920; 3rd edition 1921; 4th edition 1928; 5th edition 1937
- Volume 2: *Einführung in die Mechanik deformierbarer Körper* (Introduction to the mechanics of deformable bodies); 1st edition 1919; 2nd edition 1922; 3rd edition 1931
- Volume 3: *Einführung in die Theorie der Elektrizität und des Magnetismus* (Introduction to the theory of electricity and magnetism); 1st edition 1922; 2nd edition 1928; 3rd edition 1937
- Volume 4: *Einführung in die theoretische Optik* (Introduction to theoretical optics); 1st edition 1927; 2nd edition 1931
- Volume 5: *Einführung in die Theorie der Wärme* (Introduction to the theory of heat); 1st edition 1930

But in addition to this classical textbook Planck published another work that fulfills the criteria for a textbook, and that appeared between the publication of his *Einführung in die Theorie der Wärme* (Planck 1932) and his *Einführung in die theoretische Physik* (Planck 1919). This is the *Eight Lectures on Theoretical Physics*, delivered at Columbia University in 1909, upon which the final section will focus.

3.4 Eight Lectures

In the year 1905 a German-American exchange program for professors was initiated by the influential Prussian ministerial official and science policy maker Friedrich Althoff (vom Brocke 1991, 185–242). The program was funded in large part by a foundation created by the Berlin banker and patron of the sciences Leopold Koppel specifically for this purpose. In 1906 the program was expanded to include a special exchange between the Friedrich-Wilhelms-Universität in Berlin and Columbia University in New York.[9] Max Planck was among the select circle of sponsored visiting professors. In spring 1908 he accepted an invitation from the President of Columbia University to come to New York the following spring to give guest lectures. Planck later reflected upon this invitation in a letter to his colleague Wilhelm Wien in Munich, who was to travel under the aegis of the same program in 1913:

> At the time I nudged myself into accepting the invitation, but I must say that I absolutely did not regret it; on the contrary, after the fact I am very glad that I acquiesced to the idea. I may not have learned much over there in terms of direct science, but I received many suggestions and motivations, and outside science this journey brought me more than any other I have ever made. My trip lasted from early April to late May. During my stay there I had to hold a lecture every Friday and Saturday for four consecutive weeks; apart from that I was free and could use the intervening periods for trips to Washington, Boston, Ithaca, Niagara Falls, etc. Of course it is not possible to give anything conclusive in the

[9] President to Hallock, 30 April 1908. Columbia University Archives NYC, Central Files. Hallock Papers.

> lectures, as the time is much too short for that, and the educational background of the listeners too difficult to control besides. Therefore the only thing one can do is make a suitable selection. But this, too, has its pleasant aspects. For of course, you must take for your lecture precisely those matters at which you are best, for which the least work is needed in preparation, and there is no harm done if the topics of the various lectures are only loosely or not at all connected. In any case it is advisable to complete your preparation as much as possible before departure, for over there one is from the very outset so completely occupied with visits, invitations, sightseeing, and field trips, that there is no longer any opportunity for true collection. Initially I was quite dazed by this hustle and bustle, but after a while I succumbed to a kind of couldn't-care-less attitude, and then everything went fine.[10]

As the overarching topic of his New York lectures Planck selected "The present system of theoretical physics"[11] (Planck 1915). He thereby picked up where his cycle of lectures on theoretical physics in Berlin had left off, since in the summer semester of 1894 this cycle had closed with a one-semester course about the "System der gesamten Physik" (System of the whole of physics). In his eight lectures in New York, Planck attempted "to depict the present state of the system of theoretical physics" and to convey to his audience those principles "which dominate today's physics, the most important hypotheses of which it avails itself, the great thoughts that have penetrated the field especially in recent years"[12] (Planck 1915, 2). Even if Planck did not attempt to impart in his lectures the state of theoretical physics per se, but rather to impart merely a kind of overview of the system of theoretical physics, these lectures can be regarded as a textbook. After all, Planck's purpose was to explain his view of contemporary physics and make its principles comprehensible to his American students and colleagues. The lectures, which were intended for publication from the outset,[13] were on the following topics:

1. *Einleitung. Reversibilität und Irreversibilität* (Introduction. Reversibility and Irreversibility)
2. *Thermodynamische Gleichgewichtszustände in verdünnten Lösungen* (Thermodynamic States of Equilibrium in Dilute Solutions)
3. *Atomistische Theorie der Materie* (Atomic Theory of Matter)
4. *Zustandsgleichung eines einatomigen Gases* (Equation of State for a Monatomic Gas)
5. *Wärmestrahlung. Elektrodynamische Theorie* (Heat Radiation. Electrodynamic Theory)
6. *Wärmestrahlung. Statistische Theorie* (Heat Radiation. Statistical Theory)
7. *Allgemeine Dynamik. Prinzip der kleinsten Wirkung* (General Dynamics. Principle of Least Action)
8. *Allgemeine Dynamik. Prinzip der Relativität* (General Dynamics. Principle of Relativity)

[10] Planck to Wien, Berlin 9 October 1912. Staatsbibliothek zu Berlin, Manuscript Department. Wien Papers.
[11] "Das gegenwärtige System der theoretischen Physik."
[12] "den gegenwärtigen Stand des Systems der theoretischen Physik zu schildern"; "welche die heutige Physik beherrschen, der wichtigsten Hypothesen, deren sie sich bedient, der großen Gedanken, welche gerade in neuerer Zeit in sie eingedrungen sind."
[13] They appeared in 1910, published by S. Hirzel in Leipzig; an American translation was published in 1915 by Columbia University Press, New York.

In his lectures, Planck develops a picture of physics that could fairly be designated, as opposed to the mechanical or the electrodynamic worldview, the thermodynamic worldview. This view is characterized by Planck's belief that the principles of thermodynamics are fundamental for a basic understanding of physics. In this vein, he differentiates all physical processes into reversible and irreversible. This division, along with a comprehensive discussion of the second law of thermodynamics, makes up the content of the first lecture. Planck illustrates the "rich fertility" of this approach in his second lecture, based on the laws of thermodynamic equilibrium. Thermodynamic equilibrium is:

> that the state of a physical configuration which is completely isolated, and in which the entropy of the system possesses an absolute maximum, is necessarily a state of stable equilibrium, since for it no further change is possible. (Planck 1915, 21)

For in nature entropy can only grow; it cannot decrease in closed physical systems. Planck demonstrates how strongly this finding shapes all physical and chemical processes using the example of the theory of dilute solutions, whose individual laws derive from this basic principle. Incidentally, his two introductory lectures adhere very closely to the systematization of his *Vorlesungen über Thermodynamik*. In his third lecture, he then links the concept of entropy with atomistic theory, and discusses at length the relationship Boltzmann established between entropy and probability states. Using this fundamental relationship, in the fourth lecture, he derives the laws applicable to gases in equilibrium—Maxwell's velocity distribution, and Boyle's, Gay-Lussac's and Avogadro's laws. In the fifth and sixth lectures, the problems of radiative equilibria are finally discussed, in the context of thermodynamic observations and with the help of statistical theory. In this way, the lectures highlight Planck's path to the quantum hypothesis and demonstrate the historical derivation of Planck's law. The seventh lecture is devoted to general dynamics or, alternatively, mechanics, with a focus on examining the principle of least action, which dominates "all of mechanics as well as all other physics"[14] (Planck 1915, 122). This is illustrated through applications to mechanics, electrodynamics, and thermodynamics. In the closing lecture, a hymn is sung to the revolutionary importance and far-reaching consequences of Einstein's theory of relativity; in a postcard to Max Laue he even speaks of having made, "propaganda here for the principle of relativity."[15] According to Planck,

> it surpasses in boldness everything previously suggested in speculative natural phenomena and even in the philosophical theories of knowledge: non-euclidian geometry is child's play in comparison […] The revolution introduced by this principle into the physical conceptions of the world is only to be compared in extent and depth with that brought about by the introduction of the Copernican system of the universe. (Planck 1915, 120)

3.5 Conclusion

In historical perspective, it seems almost bizarre that Planck's own revolutionary achievement, the quantum hypothesis, received almost passing treatment in his lectures and anything

[14] "die gesamte Mechanik ebenso wie die übrige Physik".

[15] Planck to Laue, Washington 28 April 1909. Archive of the Max Planck Society (AMPG), Dept. Va, Rep. 11, No. 566.

but center stage. Four years later, Wilhelm Wien made up for this, when holding his lectures at Columbia University on the general topic of "Recent problems in theoretical physics"[16] (Wien 1913). In them, Wien not only payed tribute to Planck's merits as the pioneer of quantum theory, but also focused in particular on applications of the quantum hypothesis to the theory of specific heat, to X-rays, and to electron theory that had succeeded in the interim (Wien 1913).

In reviewing Planck's work as a textbook author, it is striking that, despite his manifold activities in this field, he did not write an independent text about quantum theory. This is also true, by the way, of his nearly forty years of lecturing, which included not a single special lecture about quantum theory, and from which all of his textbooks originated to one degree or another. Thus Planck dealt with the (older) quantum theory exclusively in the context of the theory of heat radiation, demonstrating once again his conservative attitude to the development of quantum theory based on his quantum hypothesis.

Abbreviations and Archives

Hallock Papers	Columbia University Archives, Central Files, William Hallock, New York City
Wien Papers	Staatsbibliothek zu Berlin, Stiftung Preußischer Kulturbesitz, Manuscript Department
AMPG	Archive of the Max Planck Society, Berlin

References

vom Brocke, Bernhard (1991). Internationale Wissenschaftsbeziehungen und die Anfänge einer deutschen auswärtigen Kulturpolitik: Der Professorenaustausch mit Nordamerika. In: *Wissenschaftsgeschichte und Wissenschaftspolitik im Industriezeitalter. Das "System Althoff" in historischer Perspektive*. Ed. Bernhard vom Brocke. Hildesheim: LAX. 185–242.

Ebeling, Werner and Dieter Hoffmann (2008). Max Planck und die Thermodynamik. In: *Max Planck. Über thermodynamische Gleichgewichte*. Ed. Werner Ebeling and Dieter Hoffmann. Frankfurt am Main: Harri Deutsch. vii–xxiv.

Hermann, Armin (1971). *The Genesis of Quantum Theory 1899–1913*. Cambridge, MA: The MIT Press. Original German edition: *Frühgeschichte der Quantentheorie*. Physik Verlag, Mosbach, 1969.

Joos, Georg (1932). *Lehrbuch der theoretischen Physik*. Leipzig: Geest & Portig.

Kuhn, Thomas S. (1970). *The Structure of Scientific Revolutions*. Chicago: The University of Chicago Press.

Planck, Max (1897). *Vorlesungen über Thermodynamik*. Leipzig: Veit.

— (1906). *Vorlesungen über die Theorie der Wärmestrahlung*. Leipzig: Johann Ambrosius Barth.

— (1910). *Acht Vorlesungen über theoretische Physik*. Leipzig: S. Hirzel.

[16] "Vorlesungen über neuere Probleme der theoretischen Physik."

Planck, Max (1912). *Vorlesungen über die Theorie der Wärmestrahlung*. 2nd ed. Leipzig: Johann Ambrosius Barth.
— (1915). *Eight Lectures on Theoretical Physics*. New York: Columbia University Press.
— (1919). *Einführung in die theoretische Physik,* 5 vols. Leipzig: S. Hirzel. Published between 1919–1930.
— (1930). *Theorie der Wärme*. Leipzig: S. Hirzel.
— (1932). *Einführung in die Theorie der Wärme*. 2nd ed. Leipzig: S. Hirzel.
— (1949). *Scientific Autobiography and Other Papers*. New York: Philosophical Library.
Sommerfeld, Arnold (1943a). *Mechanik*. Leipzig: S. Hirzel.
— (1943b). *Vorlesungen über theoretische Physik*. Leipzig: S. Hirzel. 9 vols. published between 1943–1952.
— (2000). *Wissenschaftlicher Briefwechsel,* 2 vols. Berlin: GNT–Verlag.
Wien, Wilhelm (1913). *Vorlesungen über neuere Probleme der theoretischen Physik*. Leipzig und Berlin: B.G. Teubner.