Book Reviews

A Transformation in Physics

Black-Body Theory and the Quantum Discontinuity, 1894–1912. THOMAS S. KUHN. Clarendon (Oxford University Press), New York, 1978. xviii, 328 pp. $24.

The beginning of modern or quantum physics is usually associated with the German theoretical physicist Max Planck's celebrated study of the black-body problem at the turn of this century. Physicists at the time referred to the problem as one of "black radiation." That shorthand has a paradoxical ring, which proved unintentionally fitting; for the problem of black radiation was destined to generate a series of "paradoxes" that would transform the classical physical theories by which Planck originally solved the problem.

From the middle of the 19th century, physicists had studied the properties of a "black body," which may be represented by a cavity with perfectly absorbing, or black, walls maintained at a uniform temperature and filled with radiation of all wavelengths. In equilibrium the radiation is characterized by a distribution function or law, which describes the way the intensity or energy of the radiation is distributed over all wavelengths at the given temperature. Independent of the material of the walls and the dimensions of the cavity, the distribution law has a "universal" nature, which Planck repeatedly noted. He believed that it had great significance for our understanding of the physical world.

If you imagine the cavity to contain microscopic, oscillating electric currents, or "resonators," that absorb and emit electromagnetic radiation, you have imagined the form of the black body that Planck studied from the mid-1890's. It was from his study of this abstract, nearly featureless, idealized cavity, consisting of radiation and resonators, that Planck derived his famous distribution law.

For Kuhn, as for any student of the origin and development of scientific theories, Planck presents a fascinating subject. When he published his conclusive distribution law in 1900, Planck was over 40, which is to say he was no longer young by the harsh way physicists have of reckoning their productive years. His derivation of the distribution law called on imaginative powers of a high order in one whose inclination was to develop physical theory through a methodical application of the most secure principles. His route to the distribution law revealed his willingness to adopt approaches in theoretical physics that he was initially unsympathetic to. He derived the law with the help of statistical approaches, which he had earlier opposed in the interest of his view of the second law of thermodynamics as a kind of canonical "absolute" in physics. He spent the "most strenuous" weeks of his life in 1900 in search of what was to become the quantum theory of black-body radiation, and in the process he immersed himself more deeply than ever in statistical thinking. When he recalled the intellectual drama of those weeks, he suggested—or so his wording has been interpreted, Kuhn thinks mistakenly—that he had made an intellectual about-face in 1900.

In part 1 of *Black-Body Theory and the Quantum Discontinuity*, Kuhn gives us a new interpretation of what happened during Planck's strenuous weeks together with an analysis of what Planck was doing for several years before and after 1900. Part 1 traces Planck's black-body theory from 1894 to 1906; by calling the entire period the "classical phase" Kuhn challenges a long-standing historiographic tradition according to which the essential concept, discontinuity, that distinguishes "modern" from "classical" physics was introduced by Planck in 1900. Kuhn argues that it was not introduced in 1900 and that when it was it was not by Planck.

There are several fine recent accounts of Planck's quantum theory of black-body radiation, which Kuhn's study "departs" from in, as he says, both senses of the word. Kuhn's disagreement with these accounts is based not primarily on new unpublished sources, though he uses some, but on the published physical papers and treatises. In the preface he explains that he had intended to write a book on the "quantum conditions" but was deflected from it by his reading of Planck's black-body papers. He gives us his new reading of Planck in part 1 of the different book he has written.

Kuhn describes Planck's developing attitudes toward mechanical and electromagnetic explanation in physics, atomism, kinetic theory of gases, statistical approaches in thermodynamics, absolute laws and units, and universal constants of nature, among other things; and he describes Planck's approaches to a series of highly technical problems arising from his model of a black body, his means for pursuing his principal goal of deriving the irreversibility of the second law of thermodynamics from conservative effects. It is a central purpose of Kuhn's to show that in the course of grappling with such problems Planck increasingly turned to and assimilated the views of the Austrian theoretical physicist Ludwig Boltzmann on the role of statistics and disorder in the foundations of the second law.

In 1899 Planck thought that he had brought to completion a long series of publications on black-body research. In addition to proving the irreversibility of the second law and giving an electromagnetic entropy function and with it an analysis of equilibrium, he had rederived the distribution law that Wilhelm Wien had recently announced and that agreed with measurements on black-body radiation. Owing to new black-body measurements carried out in Berlin, however, Planck realized that he had not yet completed his "program." His work to date prepared him to respond promptly to the experiments. Late in 1900 he derived a new distribution law that agreed with Wien's in the limit of short wavelengths and that also agreed, as Wien's did not, with the new measurements at longer wavelengths. The first derivation had an ad hoc quality that could not long satisfy Planck, whose concern was always with fundamentals. So there followed those most strenuous weeks of Planck's life, in which he sought to invest his distribution law with physical significance—"at any cost." His new derivation—or derivations, since he produced two about the same time—he later characterized as an "act of desperation." In his memory, at least, something of the traumatic always clung to it.

By 1900, according to Kuhn, Planck had used all but one of Boltzmann's statistical methods of treating the second law. The missing one was the combinatorial analysis of "complexions" that Boltzmann had introduced together with his probabilistic definition of entropy in 1877 and that had seldom been referred to since, by himself or others. For counting complexions in his own theory, Planck in 1900 turned to Boltzmann's combinatorials and probabilistic entropy, being the first, Kuhn thinks, to use them after Boltzmann. Kuhn sees in Planck's work in 1900 a continuing and deepening involvement in Boltzmann's ideas, not a first acceptance of them, not an about-face.

Although Planck's program closely paralleled Boltzmann's, there were differences in their combinatorial analyses, having to do in large part with differences between Planck's electromagnetic and Boltzmann's molecular systems. One striking difference was that, unlike Boltzmann's, Planck's energy elements did not become vanishingly small once the analysis was done. For theoretical and experimental reasons they had to remain finite.

For his combinatorial count, Planck divided the continuum of energy available to resonators into elements of fixed size. The size of an "energy element" or, after 1909, "quantum" was $h\nu$, where ν is the frequency of a resonator and h is a universal natural constant entering Planck's radiation law. The constant now bears Planck's name and provides a continuous thread through the history of nonclassical physical theory.

Kuhn insists that classical theory governed resonator emission and absorption. Planck's resonator energy was to be found anywhere within the $h\nu$. It was continuously variable, not restricted to the energy element or any multiple of it. This claim Kuhn speaks of as his "historiographic heresy."

The rest of the story can be quickly told. From the combinatorial count together with Boltzmann's logarithmic relation between probability and entropy, Planck derived in an "unexceptionable" way a necessarily new form for the entropy of a resonator. That entropy with the aid of his earlier theory yielded the new distribution law. For a second time, Planck's work on the black-body problem seemed—for the moment—essentially completed.

Planck sensed something of the magnitude of his achievement. His son recalled that Planck told him at the time that he had made the greatest discovery in physics since Newton, and we have reason to believe that Planck really did say something like that. What he no doubt meant was not that he had discovered a physics that would replace Newton's but that he had discovered the universal natural constants h and k. The second of these related entropy to the logarithm of probability; Planck called it Boltzmann's constant, and at the time it promised to be the more significant of the two.

In part 2 of Kuhn's book, Planck's law continues to play a major role, but Planck himself does not. Only at the end of the period it covers, 1905–1912, did he do more original work on black-body theory, though his work in the meantime bore on his concern to understand the physical significance of the mysterious constant h. Other physicists enter here, those who first recognized a quantum discontinuity and others who followed them. For several years there were few theoretical responses to Planck's derivations, as black-body theory remained an "esoteric specialty." Then, independently, Paul Ehrenfest and Einstein in 1906 argued that Planck's law demanded energy discontinuity. Einstein's argument was the more general and compelling of the two, and "in a sense, it announced the birth of the quantum theory." Einstein came to Planck's law from profound studies in statistical thermodynamics, which were independent of Planck's work. Einstein would, Kuhn speculates, have arrived at Planck's distribution law if Planck had never lived.

Einstein and to a lesser extent Ehrenfest hold center stage in part 2, as Planck did in part 1. However, young and relatively unknown as they were, Einstein and Ehrenfest lacked the authority of their older, highly respected colleague H. A. Lorentz. When Lorentz argued for discontinuity from 1908, he persuaded Planck and probably others. "Conversion" was under way.

Until 1910 publications on the quantum dealt mainly with black-body radiation. After that they dealt increasingly with newer topics, the most important of which, specific heats, Einstein introduced in 1907. The quantum now attracted an audience that extended beyond the small coterie of black-body experts. The convening of the first Solvay Congress in 1911 reflected a growing interest in the quantum. At first only Germans and those in the German intellectual sphere were persuaded of discontinuity and of the consequent need for reform of classical mechanics or electrodynamics or both. At the end of the period, however, physicists outside Germany had begun to take notice. Part 2 concludes with the observation that "the first stage of the conceptual transformation leading from classical to modern physics was complete."

That might have concluded the book, but it does not. The book closes on itself, returning at the end, in a short part 3, to the figure and the themes it began with. This "second close" deals again with Planck, who from 1910 worked almost exclusively on quantum problems for 15 years or so. The first result of his renewed activity was his so-called "second theory" in 1911. In this theory the energy of a resonator or "oscillator," as he now called it, varied continuously, and it absorbed radiation continuously. Discontinuity entered only in the emission of radiation. But it did enter; Kuhn argues that it was Planck's first theory to admit discontinuity and that it was not, as it has been considered, a futile rearguard action of a conservative thinker. Like the first, the second close of Kuhn's book refers to the proliferation of researchers and research problems from around 1912, testifying to the continuing and increasing fruitfulness of the theoretical ideas set in train by Planck's work from the mid-1890's.

It should be clear by now that much of Kuhn's study is about the development and replacement of scientific concepts. In this it belongs to a distinguished tradition in the history of science. Analyzing phraseology, shifts in word usage, and mathematical nuances, Kuhn bases his conceptual analysis on a close reading of a relatively small selection of critical texts. The contributors to black-body theory were few, so that Kuhn can discuss their works individually, often in detail. Only toward the end of his book do individual contributors and their contributions merge into anonymous numbers and logarithmic growth curves.

Kuhn has written a major study of the genesis and early years of the quantum theory, with emphasis on the emergence of the "concept of a discontinuous physics." He offers a new interpretation of Planck's work in parts 1 and 2, largely based on his new reading of Planck's—at times "condensed" and "obscure"—papers alongside Boltzmann's. To the extent that students of the history of physics are persuaded—or converted—by Kuhn's reading, the historical picture of this part of quantum physics will be different. Certainly, from now on readings of Planck's papers will be richer for Kuhn's book. Much of the material on responses to Planck's theory is brought together systematically for the first time in part 2; a coherent historical picture of this part of quantum physics can hardly be said to exist before Kuhn's book. Finally, because Kuhn takes pains to set black-body and related researches in their physical context, he provides a valuable introduction to major themes in theoretical physics around the turn of this century. All parts of Kuhn's book should be—and will be—critically read and discussed by professional students of the development of modern physics.

Readers of *The Structure of Scientific Revolutions* are familiar with Kuhn's concern with the workings of scientific communities as producers and validators of natural knowledge. As Kuhn's new book offers a historical illustration of those workings, readers will be aware of a continuity of some of his concerns. The introduction and assimilation of a concept such as quantum discontinuity, which calls for the restructuring of traditional theory, hold a natural interest within a theory of scientific change. Readers will not meet "paradigm," "exemplar," "disciplinary matrix," "normal science," "anomalies," "crises," and "scientific revolution," terms familiar from *Structure*. But they will meet other familiar terms that will orient them within the insulated world that Kuhn portrays of scientific specialists working within the circle of their professional concerns. Here black-body physicists address themselves to technical "puzzles," and they do or do not "convert" to discontinuity. They give a "revolutionary reformulation" to Planck's theory not from any wish to overthrow "classical" theories but as a response to Planck's "classical" theory with its unanticipated problems. Early quantum theorists correspond, publish, usually in the leading German physics journal, *Annalen der Physik*, and debate at meetings as they seek agreement on the question of admitting some form of quantum discontinuity. Like *Structure*, *Black-Body Theory* will interest historians, natural, social, and psychological scientists, philosophers, and other students of scientific change.

In closing it should be noted that *Black-Body Theory* is less accessible than *Structure*. It is less accessible, too, than Kuhn's *The Copernican Revolution*, in which he argues that to fully understand the origins of the great intellectual changes associated with the "Copernican Revolution" we must understand the technical problems at issue and the recondite minutiae that occupied Copernicus and other astronomers. In this new book the understanding of the past of physics that Kuhn wishes to impart requires highly technical discussions indeed. Although he gives frequent summaries of the technical discussions and explanations of what he is going to discuss next and why, for full comprehension readers need a good grasp of the classical theories—above all of thermodynamics, kinetic theory, and Maxwell's theory—that converge in Planck's work on black-body radiation. Readers who know enough physics and who want to understand one of the most far-reaching conceptual changes in the history of physics will greatly profit from *Black-Body Theory and the Quantum Discontinuity, 1894–1912*.

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Historical Genetics

The Genetics of the Jews. A. E. MOURANT, ADA C. KOPEĆ, and KAZIMIERA DOMANIEWSKA-SOBCZAK. Clarendon (Oxford University Press), New York, 1978. viii, 122 pp. $34.50. Research Monographs on Human Population Biology.

Recent years have seen the discovery of a variety of genetic markers, such as serum and enzyme variants. The gene frequencies of such markers and of blood groups usually differ between human populations and can be utilized to assess the affinities of various populations and racial groups. Mourant and his co-workers have been in the forefront in consolidating the scattered information in this field. Their monumental volume *The Distribution of Human Blood Groups and Other Polymorphisms* (1976) is the key reference in this field. They now address the genetics of Jews.

The Jews of the world have a common religion or at least common cultural traditions and, for some large groups, a common language, namely Yiddish among Ashkenazi Jews and Ladino among Sephardic Jews. Whether the various Jewish populations have common genes has been less clear. Mourant and his coauthors in this book trace the history of various Jewish groups and integrate the historical data with an assessment of gene frequencies for various markers compiled from the world literature.

After a succinct and clear exposition of the genetic polymorphisms referred to in the book, the early history of Jews is described. Chapters are then devoted to various Jewish populations—Samaritans, Oriental Jews, Yemenite Jews, various Jewish groups of Africa, and Karaites, as well as the currently most numerous Ashkenazi and Sephardic Jews, that is, Jews of Central European and Spanish origin.

Each major Jewish community tends to resemble genetically the indigenous population of the region whence it originated. Ashkenazi and Sephardic Jews have many resemblances in different genetic systems and are therefore considered to have a common "Palestinian" origin. Earlier assessments of genetic affinities were largely based on the ABO blood groups and led to the conclusion that Ashkenazi Jews resembled closely the populations of the various European areas where they lived. The analysis by Mourant and his coauthors of the total evidence suggests the genetic distinctiveness of this and other Jewish populations. Generally, however, some similarity between Jewish subcommunities and the people among whom they have lived more recently can be detected. Claims (recently resurrected by Arthur Koestler in his book *The Thirteenth Tribe*) that Ashkenazi Jews are genetically derived entirely from the Khazars (a Turkic tribe that embraced Judaism and lived between the Caspian and the Black seas between the 6th and the 9th centuries) appear highly unlikely on the evidence of genetic markers. It is possible, however, that the Crimean and Lithuanian Karaites (a sect that accepts the Old Testament but rejects later interpretations such as the Talmud) as well as the Krimchaks (Orthodox Jews of the Crimea) may be descendants of the Khazars. In fact, the Nazis spared the Karaites from extermination in the early 1940's because of the already known blood group differences between them and the general Ashkenazi Jewish population. African admixture of the order of 5 to 10 percent in most Jewish groups (including Ashkenazim) has been documented by a higher frequency of the typically African rhesus genotype *cDe*. This African marker was presumably acquired by the Jews through admixture from slaves and concubines during their prolonged sojourn in Egypt.

The analysis of Mourant and his coauthors is wide-ranging. Their assessments do not use the various quantitative methods developed by population geneticists to study intermixture and population affinities, but several of their conclusions have already been independently confirmed, refined, and extended by recent papers dealing with additional Jewish gene frequencies on old and new markers (*1–3*) and using more quantitative admixture (*4*) as well as multivariate methods of analysis (*5*). However, the analysis by Mourant and his coauthors covers many more Jewish populations than the newer work.

Several diseases unique to various Jewish populations are briefly discussed in a separate chapter. The survey of the literature here is somewhat selective and is less complete than that for polymorphisms. Mourant and his coauthors believe