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De-anthropomorphizing energy and energy conservation: The case of Max Planck and Ernst Mach

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ABSTRACT

Discussions on the relation between Mach and Planck usually focus on their famous controversy, a conflict between 'instrumentalist' and realist philosophies of science that revolved around the specific issue of the existence of atoms. This article approaches their relation from a different perspective, comparing their analyses of energy and energy conservation. It is argued that this reveals a number of striking similarities and differences. Both Mach and Planck agreed that the law was valid, and they sought to purge energy of its anthropomorphic elements. They did so in radically different ways, however, illustrating the differences between Mach's 'historical' and Planck's 'rationalistic' accounts of knowledge. Planck's attempt to de-anthropomorphize energy was part of his attempt to demarcate theoretical physics from other disciplines. Mach's attempt to de-anthropomorphize energy is placed in the context of fin-de-siècle Vienna. By doing so, this article also proposes a new interpretation of Mach as a philosopher, historian and sociologist of science.

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1. Introduction

The relation between Max Planck (1858–1947) and Ernst Mach (1838–1916) has usually been studied from the perspective of their famous controversy, which became public in 1908. At first sight it looks like an ideal-type, text-book illustration of the differences between two traditional and opposite positions in the philosophy of science: realism and positivism (or instrumentalism). Indeed, the controversy has been used for the purpose of illustrating these positions in an introduction to the philosophy of science.[1] It is widely acknowledged that the central question of this debate was the existence of atoms. Whereas Mach maintained that atoms were no more than theoretical fictions, Planck believed they were as real as planets (Heilbron, 1986, p. 49). According to the received view, Planck was initially a Machian himself and began to change his opinion on atomism following the discovery of energy quanta and his acceptance of Ludwig Boltzmann's (1844–1906) statistical analysis of the second law of thermodynamics (Hiebert, 1968, 1971; Blackmore, 1972, p. 219; Kuhn, 1978, pp. 22, 29ff; Heilbron, 1986, pp. 9–21, 44). This conversion partly explains his violent revolt against Mach. Although Mach's positivism initially found much support within the academic community, Planck's atomistic realism was vindicated in the end. Theoretical developments, ranging from Boltzmann's statistical interpretation of the second law of thermodynamics to Einstein's account of Brownian motion, were all interpreted as refutations of both Mach's anti-atomism and his philosophy of science. Thus, Brush (1968) judged that 'the final verdict has to go against Mach's methodology' (p. 211).[2]

This article approaches the relation between Planck and Mach from a different perspective. Instead of focusing on their controversy and the issue of atomism, it compares their analyses of the concept of energy and the law of energy conservation. Energy was arguably at least as important as atomism for their thoughts on science. Mach's and Planck's belief that the conservation of energy was the single most fundamental law of science reflected the scientific consensus of the late nineteenth century. Already in their youth, the law left a major impression on them, as both recalled having first heard of it at the gymnasium (Mach, 1923, p. 242; Planck, 1967, p. 7). Energy accompanied their

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[1] See for example Toulmin (1970, pp. 1–52) and Kroes (1996, pp. 48–64).

[2] Apart from contemporary analyses of the Mach–Planck controversy, these are a few of the central references: Gerhards (1912), Kropp (1951/1952, pp. 436–450), Brush (1968), Blackmore (1972, pp. 216–227), Feyerabend (1984), Heilbron (1986, pp. 47–60), Fuller (1994a, 2000, pp. 96–149). Also see the references at the end of this article.

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academic careers as well. In 1871, Mach gave a lecture entitled *Die Geschichte und die Wurzel des Satzes von der Erhaltung der Arbeit*, which adumbrated much of his later philosophy (Mach, 1909, p. iii; Banks, 2003, pp. 24, 181). Energy was also one of the central examples in Mach's analysis of scientific concepts. In 1887, Planck published *Das Prinzip der Erhaltung der Energie*, which can be read as an attempt to delineate the emerging specialty of theoretical physics. These early works are central to the argument that follows. Planck and Mach's enduring commitment to them is supported by the fact that they published new editions of them when the controversy became public.

A comparison of Planck and Mach's views of energy and energy conservation reveals that in spite of numerous differences, they actually had a remarkably similar agenda. Both sought to purge science of anthropomorphic elements and to 'disenchant' the world—to adopt Max Weber's phrase. However, it will be argued that this shared aim originated from different motivations. Planck primarily sought to professionalize (theoretical) physics. Seth (2007) has reminded us of the oft-neglected fact that 'theoretical physics was still a discipline under construction in the 1890s' (p. 31).[3] This article supports his contention that Planck's work 'must be seen as part of a process of creating' (p. 32) and shaping theoretical physics. Mach's de-mystification of energy, however, must be understood in a cultural context. In order to develop a novel interpretation of Mach's philosophy, his work will be treated more elaborately than Planck's. His philosophy is also widely acknowledged to be the most difficult to interpret. The contrasting ways in which Mach and Planck de-anthropomorphized energy corresponded to these different motivations. Planck did so as a physicist; Mach as a philosopher, historian and sociologist of science.[4] As a result, there were subtle but fundamental and highly significant differences in the ways in which they phrased the law of energy conservation. And, if proverbs speak truths, it is in these details that God and the devil are to be found.

2. Max Planck and the foundations of theoretical physics

> And so it occurred that, as the primary law, which possesses validity independent of human beings, I received the principle of the conservation of energy as if it was a message of salvation. Unforgettable to me is the illustration [Hermann] Müller [Planck's teacher of mathematics at the gymnasium, D.W.] gave us of a bricklayer, who drags a heavy tile up on the roof. The work, which he thus delivers, is not lost, but remains stored unconsumed, perhaps for years, until perhaps one day the tile comes lose and falls upon somebody's head below (Planck, 1967, pp. 7–8; quoted in Kuhn, 1978, p. 14; cf. Heilbron, 1986, p. 10).[5]

Müller's comical illustration of the law of energy left a deep mark on the young Planck's mind. The tile that unexpectedly falls on an innocent passer-by provides a graphic image of energy conservation's independency of human beings. Being a realist, Planck insisted that the world is not our will and representation. The recollection had symbolic meaning to Planck; he reported it on the first page of his *Wissenschaftliche Selbstbiographie*. The moment when he discovered his vocation or calling, as described by Planck, reads like a religious conversion experience.[6] Only with hindsight could he be fully aware of the significance of the law for his scientific career. He was associate professor of theoretical physics in Kiel when he published *Das Prinzip der Erhaltung der Energie*, his first and only major work on the conservation of energy, in 1887. The book was initially intended as a contribution to a prize-essay competition initiated by Göttingen University. Planck won the second prize; nobody won the first.

In the preface, Planck explained that he had not won the first prize because he hardly discussed the relation between the conservation of energy and Wilhelm Weber's force law—a contentious topic between the physicists at Berlin and Göttingen (Planck, 1921, p. xii). The 'speculative' or 'deductive' approach that was favored in Göttingen was strongly rejected by Planck, who openly and repeatedly professed to accept the priority of the inductive method (Planck, 1921, pp. xii–xiii; Wegener, 2009a). Theoretical physics, he felt, was ultimately based on empirical principles. Planck did not win the essay prize, but he did succeed Gustav Kirchhoff (1824–1887) in 1889 as extraordinary professor of theoretical physics in Berlin.[7] As Heilbron (1986) comments: 'Quasi-rejection by Göttingen assisted quasi-acceptance by Berlin' (p. 12).

Heilbron (1986) has argued that around 1900 Planck 'developed clear demarcations between physics on the one hand and mathematics and philosophy, which he considered its auxiliaries, on the other. These demarcations [. . .] helped to define the scope and method of the emerging specialty of theoretical physics' (p. 39). In what follows, I shall argue that these demarcations were already developed in *Das Prinzip der Erhaltung der Energie*. The paper can be interpreted as a programmatic essay that aimed to carve out a niche for theoretical physics, a subdiscipline that Planck helped to shape. Furthermore, next to mathematics and philosophy, popular science will be identified as an equally important area from which Planck sought to distinguish the new subdiscipline.

In the introduction of his essay, Planck clearly distinguished his essay from popular, philosophical, and historical accounts of the conservation of energy. Firstly, he explicitly addressed a select group of professional physicists, not the broader audiences that were addressed by popular science. In the introduction, he remarked that almost all publications published on energy conservation in the last forty years were intended for a wider audience.

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[3] The origins of science and the disciplines are more recent than is often thought. Thus, Cunningham (1988, 1991) and Cunningham & Williams (1993) have repeatedly pointed out that what has been called 'seventeenth-century science' was actually something completely different: Natural philosophy. There is no 'modern science'; science is modern. Likewise, the German word 'Physik' has often been identified with physics, but as Stichweh (1984) has observed that 'Physik' was synonymous to natural philosophy for a large part of the nineteenth century (p. 95). In early Victorian Britain, physics 'had an indefinite varying meaning (Cannon, 1978, p. 2).' Compare McCormmach (1971): 'Planck [was] one of the first of the new specialists' (p. xvii) and 'When Planck earned his doctorate in 1879, theoretical physics had hardly begun to be acknowledged as a separate subdiscipline' (p. xviii).

[4] The meaning of this opposition will become clear in the course of this argument. Charles Coulston Gillispie (1966) wrote that 'the historian of science is likely to experience a fellow feeling for [Mach]' (p. 496).

[5] The translations are mine, except where noted, with gratitude to Bert Theunissen. 'So kam es, daß ich als erstes Gesetz, welches unabhängig vom Menschen eine absolute Geltung besitzt, das Prinzip der Erhaltung der Energie wie

(*footnote continued*)
eine Heilbotschaft in mich aufnahm. Unvergeßlich ist mir die Schilderung, die Müller uns zum besten gab, von einem Maurer, der einen schweren Ziegelstein mühsam auf das Dach eines Hauses hinaufschleppt. Die Arbeit, die er dabei leistet, geht nicht verloren, sie bleibt unversehrt aufgespeichert, vielleicht jahrelang, bis vielleicht eines Tages der Stein sich löst und unten einem Menschen auf den Kopf fällt.'

[6] Heilbron (1986) remarks that 'this doctrine spoke to the lawyer and the theologian in Planck' (p. 9). Planck came from a family of lawyers and theologians.

[7] Although initially Ludwig Boltzmann was actually the favourite candidate for the position, see: Jungnickel & McCormmach (1986, vol. 2, p. 51).