A Conservative Revolutionary – Max Planck's Worldview in Physics

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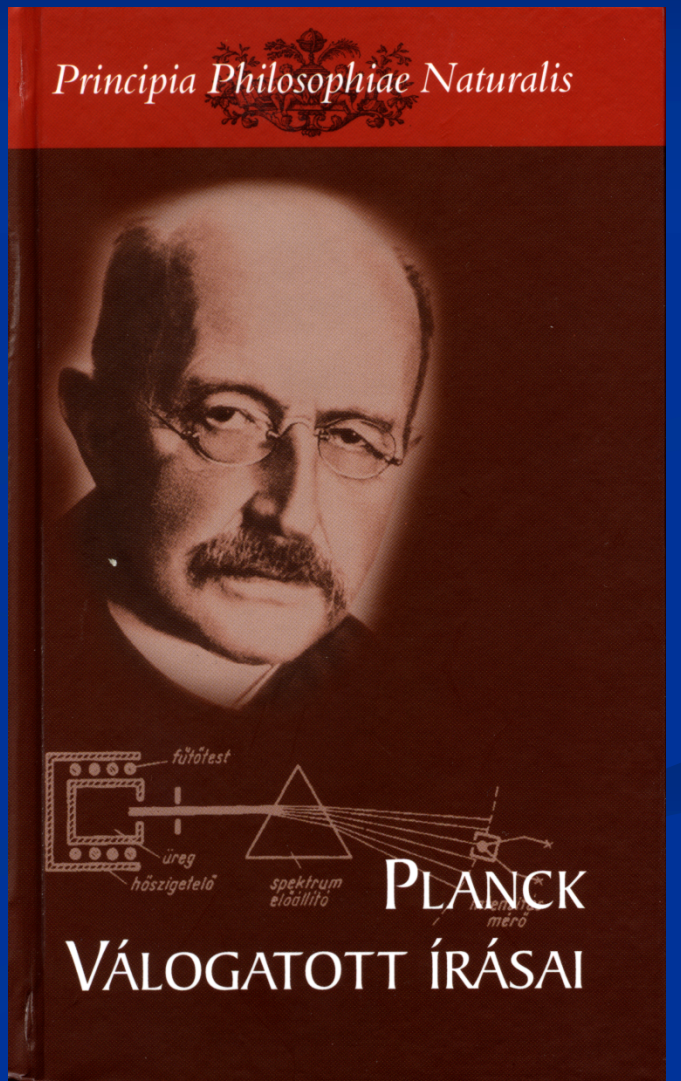

A conservative life

- 24 April 1858, Kiel
  - Noble family
    - scientists, lawyers, theologians, teachers
    - one of his ancestor from the XV. c. has descendants like Hegel, Schelling, Schiller, and Hölderlin
  - Father: professor of jurisprudence at University of Kiel
  - his conservatism, respect for traditional values, classical literacy, idealism, sense of duty, and reliability comes from this family atmosphere

- 1867-, Munich
  - secondary school
    - good student
      - accurate
      - mathematical talent
  - music
    - singing
    - he plays several instruments
  - ancient languages

- physics
  - the Philipp von Jolly story
    - the Julius Robert Mayer slip-up
    - „He described physics to me as a highly developed, nearly fully matured science, that through the crowning achievement of the discovery of the principle of conservation of energy it will arguably soon take its final stable form. It may yet keep going in one corner or another, scrutinizing or putting in order a jot here and a tittle there [in the German text ‘ein Stäubchen oder ein Bläschen’ = ‘a speck of dust or a bubble’], but the system as a whole is secured, and theoretical physics is noticeably approaching its completion to the same degree as geometry did centuries ago.”

- Lord Kelvin
  - lecture on 27 April, 1900 (extended version was published in July, 1901) about *Nineteenth Century Clouds over the Dynamical Theory of Heat and Light*
    - „The beauty and clearness of the dynamical theory, which asserts heat and light to be modes of motion, is at present obscured by two clouds. I. The first came into existence with the undulatory theory of light, and was dealt with by Fresnel and Dr. Thomas Young; it involved the question, How could the earth move through an elastic solid, such as essentially is the luminiferous ether ? II. The second is the Maxwell-Boltzmann doctrine regarding the partition of energy."
- Thomas Kuhn
  - anomalies → crisis → revolution

- 1874-, University of Munich
  - experimental physics
    - but interested in laws and fundamental principles of physics (i.e. theoretical physics)
  - mathematics
- 1877, Berlin
  - Helmholtz, Kirchhoff, Weierstrass
    - „Helmholtz obviously never prepared properly; he spoke only haltingly, picking out the needed data from a little notebook, besides consistently miscalculating at the blackboard, and we had the feeling that he was at least as bored by his presentation as we were.”

- read the works by Clausius
  - way to thermodynamics
  - perhaps the first step to became an outsider who will overcome the problems alone
- 1878, Munich
  - degree: teacher of mathematics and physics
- 1879-, Munich
  - PhD: „On the Second Law of the Mechanical Theory of Heat” (summa cum laude)
- 1885-, Kiel
  - associate professor of theoretical physics
    - ahead of Heinrich Hertz, who had been waiting for this job for two years

- 1887: with *The Principle of the Conservation of Energy* wins a Göttingen contest prize
  - an important step on the way of becoming independent: he marries his childhood girlfriend Marie Merck
- but he does continue to focus to entropy and the second law
  - as an outsider, because
    - he works in a hostile environment
    - interested in theories which then was not appreciated by the colleagues
- on his writings feels Ernst Mach's philosophical influence
- extends the methods of thermodynamical problem solving to chemistry
  - debates with Arrhenius etc.

- 1889-, Friedrich-Wilhelms-Universität (Berlin)
  - associate professor of theoretical physics
    - instead of Boltzmann and H. Hertz
    - „Planck's papers are very favourably distinguished from those of the majority of his colleagues in that he tries to carry through the strict consequences of thermomechanics constructively, without adding additional hypotheses, and carefully separates the secure from the doubtful ... His papers ... clearly show him to be a man of original ideas who is making his own paths [and] that he has a comprehensive overview of the various areas of science.” (recommendation by Helmholtz)
  - electro- and thermochemistry
  - musical acoustics
  - his authority grows

- 1892-, Berlin
  - full professor
  - 1894- proper member of the Prussian Academy of Sciences
  - against Oswald's energetism
    - against the analogy of the flow of heat and water etc.
    - but Boltzmann's arguments - coming from other sources - were more important

- „It is one of the most painful experiences of my entire scientific life that I have but seldom — in fact, I might say, never — succeeded in gaining universal recognition for a new result, the truth of which I could demonstrate by a conclusive, albeit only theoretical proof. This is what happened this time, too. All my sound arguments fell on deaf ears. It was simply impossible to be heard against the authority of men like Ostwald, Helm and Mach. … This experience gave me also an opportunity to learn a fact — a remarkable one, in my opinion: A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it.” (A Scientific Autobiography)
  - this is the Planck’s Principle at some historians, philosophers, and sociologist of science - as one of the extreme ways of development in science
    - the opposite extreme is Popper’s Principle: science develops through refutations; scientists give up their theories after the first refuting experiment

- 1894-
  - attempts with the theory of thermal radiation
- 19 October 1900, *On an Improvement of Wien's Equation for the Spectrum*
- 14 December 1900, *On the Law of Distribution of Energy in the Normal Spectrum*
  - „It was told by Planck's son that his father spoke to him about his new ideas on a long walk through the Grunewald, the wood in the suburbs of Berlin. On this walk he explained that he felt he had possibly made a discovery of the first rank, comparable perhaps only to the discoveries of Newton.” (Heisenberg)

- Testifying
  - that he is an outsider:
    - the only scientist, who approached the problem from the side of entropy;
  - that based on his conscientiousness, honesty, and consistency in research (which were part of his conservativism)
  - he is able to overcome even himself:
    - looking for the absolute laws, earlier he had no good opinion on Boltzmann's atomistic and probabilistic methods;
    - he still accepted them for the sake of result
      - „I was ready to sacrifice everyone of my previous convictions about physical laws." (letter to R. W. Wood, 1931)

- The revolutionary result was astonishing for him:
  - twelve years work to fit it to the classical physics
    - realized that certain classical results he could get back with the limit $h \rightarrow 0$ („The classical theory can simply be characterized by the fact that the quantum of action becomes infinitesimally small.”)
    - His goal: „The introduction of the quantum of action *h* into the theory should be done as conservatively as possible, i.e., alterations should only be made that have shown themselves to be absolutely necessary. (1910)”
    - the atomic oscillators can only be excited with discrete energy portions, but they are behaving classically after excitation (1910)
    - the light emission happens in quantized energy portions, but otherwise the atomic oscillators are behaving classically (1912)
    - on great energies the classical and quantum formulas are parallel

- instead, Einstein, Ehrenfest, and others were working on acceptance of quantum hypothesis
- 1906-1908
  - relativity theory
    - later proposed Einstein for the directorship of Keiser Wilhelm Institute of Physics (Berlin) and membership of Prussian Academy of Sciences
      - „That he might have in his speculations, occasionally, overshot the target, as for example in his light quantum hypothesis, should not be counted against him too much …" (from Planck's recommendation)
  - thermodynamics
    - third law

- the Lise Meitner story i.e. Planck's conservativism and ability to overwhelm himself
  - the second woman in Vienna, who got a PhD in physics
  - „You have got a PhD, what do you want yet?"
  - he allowed her to attend on his lectures, but wrote to the rector: „women should be allowed to visit the lectures only at trial and at any time revocable" … „nature itself requires women to be mothers and housewives"
  - later - recognizing her talent - he made her his assistant
    - she even got permission to visit Planck's family and talk to his twin girls
  - Meitner's further work

- against Mach
  - lecture in Leiden
- 1909 his wife died
  - 1910 he marries her cousin
- 1916 his elder son was killed at Verdun, the younger prisoned in France
- 1917 Margarete died giving birth to a child
  - Emma married the widow and died in the same way
  - Planck took the tragedies stoically and nursed the two grandchildren

- 1919 Nobel-prize
  - nominated since 1907
  - The Nobel Prize in Physics 1918 „in recognition of the services he rendered to the advancement of Physics by his discovery of energy quanta.”
  - the first prize for theoretical physics
  - he continues to teach at the university
    - he has no school in theoretical physics
      - Arnold Sommerfeld in Munich; Max Born in Göttingen
    - because to some extent he is still an outsider
      - he expects from his disciples the same autonomy he had shown in his youth
      - a few excellent students (G. Hertz, Laue, Zermelo, Schlick)

- 1925 quantum mechanics
  - „Now over against this strikingly imposing and harmonious structure [classical physics including the theory of relativity] there stands the Quantum Theory, an extraneous and threatening explosive body which has already succeeded in producing a wide and deep fissure throughout the whole of the structure.” (1926)

- „ … the Quantum Theory contradicts the traditional views … the Quantum Theory unequivocally denies certain fundamental views which are essential to the whole structure of the classical theory. Hence the introduction of the Quantum Theory is not a modification of the classical theory, … it is a complete break with the classical theory.” (ibid.)
- but he hopes, that there is no paradigm-shift, the classical physics remains valid, even stronger
  - „the structure of classical Physics, which have had to be discarded as valueless under the pressure of the Quantum Theory, will be supplanted by a sounder and more adequate structure” (ibid.)

- „For a time it seemed that a complete collapse of classical Physics was not beyond the bounds of possibility; gradually however it appeared, as had been confidently expected by all who believed in the steady advance of science, that the introduction of the Quantum Theory led not to the destruction of Physics, but to a somewhat profound reconstruction, in the course of which the whole science was rendered more universal. For if the Quantum of Action is assumed to be infinitely small, Quantum Physics becomes merged in classical Physics. (1929)
- „… the foundations of the structure of classical Physics not only proved unshakable, but actually were rendered firmer through the incorporation of the new ideas” (ibid.)

- „The question may now be asked whether modern Physics differs at all from the older Physics, if all these foundations of classical Physics have remained untouched.” (ibid.)
  - the examined objects were changed
    - material point - the concept of particle
    - their localization
    - as a consequence: Heisenberg’s relation of uncertainty, which is unknown in classical physics
- but we have to keep some form of determinism and strict causality at least form epistemological point of view
  - „Actually, however, the most important advances in the study of atomic processes are due to the attempt to look for a strictly causal and dynamic law behind every statistical law.” (1926)

- 1926- retired
  - hands over the professorship to Schrödinger
  - mainly lectures on worldview issues
- 1937-
  - lectures on religious questions
- 1945 younger son was executed (because of conspiracy against Hitler)
- 4 October 1947
  - died in Göttingen

His philosophy of nature

- Preliminary note: it is not a requirement to have a coherent worldview for a physicist (or anybody).
- materialistic (realist) foundation?
  - „My original decision to devote myself to science was a direct result of the discovery which has never ceased to fill me with enthusiasm since my early youth — the comprehension of the far from obvious fact that the laws of' human reasoning coincide with the laws governing the sequences of the impressions we receive from the world about us; that, therefore, pure reasoning can enable man to gain an insight into the mechanism of the latter. In this connection, it is of paramount importance that the outside world is something independent from man, something absolute, and the quest for the laws which apply to this absolute appeared to me as the most sublime scientific pursuit in life.” (Autobiography 1943?)

- Mach's partial influence
  - e.g. in *The Principle of the Conservation of Energy* (1887)
- his action against Ostwald's energetism and the Boltzmann debate forced him to rethink the questions of his worldview
  - away from Mach
    - comparing e.g. the temperature chapter of his textbook on thermodynamics (1897) with the same part of Mach's book (1896)
      - Planck: starting from the sense of heat, reaches the absolute temperature scale, on the professional level of the age
      - Mach: starting from the sense of heat, does not accept the absolute scale, influenced by his own positivism reaches problematic results

- „The proposition stated [the second law] in this general form may be correct or incorrect; but whichever it may be, it will remain so, irrespective of whether thinking and measuring beings exist on the earth or not, and whether or not, assuming they do exist, they are able to measure the details of physical or chemical processes more accurately by one, two, or a hundred decimal places than we can. The limitations to the law, if any, must lie in the same province as its essential idea, in the observed Nature, and not in the Observer. That man's experience is called upon in the deduction of the law is of no consequence; for that is, in fact, our only way of arriving at a knowledge of natural law. But the law once discovered must receive recognition of its independence, at least in so far as Natural Law can be said to exist independent of Mind. Whoever denies this must deny the possibility of natural science.”

- „Is the physical world simply a more or less arbitrary creation of the intellect, or are we forced to the opposite conclusion that it reflects phenomena which are real and quite independent of us?” (The Unity of the Physical Universe, 1908)
  - the question has an ontological and an epistemological side and Planck gives a realist answer to both
- „If, looking back over the past, I give an affirmative answer to these questions, I am certain that this answer is, in a way, contradictory to a tendency of natural philosophy (recently introduced by Ernst Mach) which is in great favour in scientific circles.” (ibid.)
- since Mach was personally addressed, he answered and a debate began between them

- later he gave even more detailed criticism (Positivism and the Real External World, 1930)

- the positive outline of his views (The World Picture of the New Physics, 1929)
  - we start from the world of sense-perception (in physics: from measurements)
    - „Physics is an exact Science and hence depends upon measurement, while all measurement itself requires sense-perception. Consequently all the ideas employed in Physics are derived from the world of sense-perception.”
  - however we are not positivists, so we don’t stop here, but
    - „… assume the existence of another world of reality behind the world of the senses; a world which has existence independent of man …”

- unfortunately the real world
  - „… can only be perceived indirectly through the medium of the world of the senses, and by means of certain symbols which our senses allow us to apprehend. It is as though we were compelled to contemplate a certain object in which we are interested through spectacles of whose optical properties we were entirely ignorant.”
- so we need something go-between
  - „… besides the world of sense and the real world, there is also a third world which must be carefully distinguished from these: this is the world of Physics. It differs from the two others because it is a deliberate hypothesis put forward by a finite human mind; and as such, it is subject to change and to a kind of evolution. Thus the function of this world of Physics may be described in two ways, according as it is related to the real world, or to the world of the senses. In the first case the problem is to apprehend the real world as completely as possible; in the second, to describe the world of the senses in the simplest possible terms.”

- the first description is the metaphysical, the second is the positivistic one, but we have a third, too
  - „ … there is a third group of students who investigate the world from the physical point of view. They differ from the first two groups in being interested not so much in the relation between the world of physics on the one hand, and the real world and the world of sense-data on the other, as in the internal consistency and logical structure of the world of physics. These men form the axiomatic school …”
- we need the balance of all three approaches and no one-sidedness
- there were many historical fluctuations in this balance, but
  - „… we find a clear course of evolution making more or less steady progress in a definite direction; progress which is best described by saying that it adds to the content of the world of sense, rendering our knowledge more profound and giving us a firmer grasp of it. The most striking instance of this is found in the practical application of Physics.”

- along with this process
  - „… the structure of this physical world consistently moved farther and farther away from the world of sense and lost its former anthropomorphic character. Still further, physical sensations have been progressively eliminated … . Thus the physical world has become progressively more and more abstract; purely formal mathematical operations play a growing part, while qualitative differences tend to be explained more and more by means of quantitative differences.”
- perhaps it means that
  - „… as the view of the physical world is perfected, it simultaneously recedes from the world of sense; and this process is tantamount to an approach to the world of reality.”
- in any case
  - it is very important to ensure the unity of the physical world picture (all parts of it are relevant and in connection with the others)

- this is a Kantian picture
  - „And we indeed, rightly considering objects of sense as mere appearances, confess thereby that they are based upon a thing in itself, though we know not this thing as it is in itself, but only know its appearances, viz., the way in which our senses are affected by this unknown something.” (Kant: Prolegomena)
  - the two worlds are the unknowable nuomenon (the world of thing-in-itself, or essences) and the phenomenon (the world of appearences)
    - unknowable, because the space and time are *a priori* representations, forms of sensible intuition; and we have also *a priori* categories; and maybe the understanding will be distorted by them

- there is no connection between the two worlds, but according to Kant, the science can exist within the world for us (among the phenomena or appearences) with the help of synthetic *a priori* propositions
- according to Planck, this science (the physical world picture) can intermediate between the two worlds

- [and Planck's views on free will, ethical and religious problems were omitted]

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