PHYSICS IN 1900*

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The state of physics in 1900 is reviewed by making use of the documents of that year, in particular the material of the Ist International Congress of Physics. Contrary to simplified accounts which portrait 1900 as the year of revolutionary transition from classical to quantum physics it is shown that almost all physicists at that time were satisfied with classical physics and were actively enriching and expanding it.

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1. Introduction

There are several reasons why it is interesting to discuss the state of physics in 1900. Firstly, the approaching end of the twentieth century and of the second millennium is a good occasion for reflections and recapitulation, and in order to assess the progress of physics during the twentieth century we need to know its state at its beginning, hundred years ago. Secondly, it is usually believed that it was in 1900 that the transition from classical to quantum physics began. Finally, we have at our disposal a unique document, the Proceedings of the First International Congress of Physicists which took place in Paris, August 6–12, 1900 [1].

Accounts of the past events in science, and in physics in particular, are often biased. Some authors tend to evaluate physicists of the past and their work by using only the present day perspective and knowledge. It results always in a falsified picture of the past because all the mistakes, wrong turns, twists, and blind alleys which form an essential part of history, get washed away as unimportant and what remains is an orderly, straight and logical development culminating in the present. But physics never develops that way!

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In order to reconstruct the true history of physics in a given epoch we must try to look at the world through the eyes of physicists living at that time. We must try to understand the problems they saw, the methods they used to solve them, and the answers they gave at that time. The reconstruction must be based on documents. Only then we may be able to make sense of apparently illogical activities of our predecessors.

2. Some numbers

The community of physicists in 1900 was rather small. There are two independent estimates of the number of "academic" physicists, *i.e.* those employed at universities and other schools of university level. Heilbron and co-workers [2] made use of an extensive list of original documents, pertaining mostly to the USA and major countries in Western Europe. Kudryavcev [3] gave more details on the situation in Russia and Eastern Europe. Thus, the two estimates have been, to some extent, complementary (see the table). As the best estimate of the number of academic physicists in 1900 one may take for each country the larger of the two estimates. It gives a total of 1083 physicists (Fig. 1).

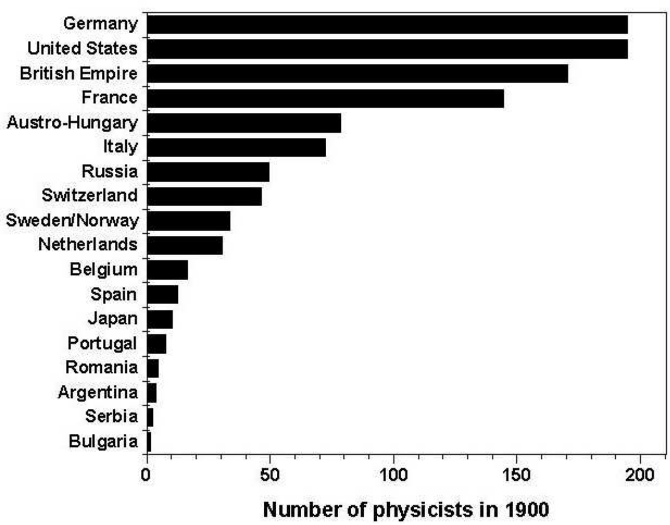

Fig. 1. Physics community in 1900

An independent check is provided by the list of authors of physics papers listed in Science Abstracts for 1900 [4]. There are altogether 1658 names listed there. However, until 1903 Science Abstracts covered electrical engineering as well as physics. About thirty percent of the listed papers could be classified as engineering and if the same proportion is also taken

Number of physicists in 1900

Country	Heilbron's estimate	Kudryavcev's estimate	Number taken	"Top" physicists (estimate 1)	"Top" physicists (estimate 2)
Argentina		4	4		
Austro–Hungary	79	53***	79	6	11
Belgium	17		17		1
British Empire*	171	~ 100	171	35	30
Bulgaria		2	2		1
France	145	~ 90	145	34	29
Germany	195	~ 120	195	52	50
Netherlands	31	~ 15	31	7	8
Italy	73	~ 50	73	7	4
Japan	11	8	11		2
Portugal		8	8		
Romania		5	5		
Russia	40	50	50	9	25
Serbia		3	3		
Spain		13	13		
Sweden/Norway**	34****		34	5	8
Switzerland	47		47	2	3
United States	195	~ 110	195	27	22
			1083	(184)	(194)

* with India and Canada

** Union until 1905

*** 33 Austrians, 8 Hungarians, 6 Poles, 4 Czechs

**** With Denmark and Finland

"Top" physicists

Estimate 1: Dictionary of Scientific Biography (ed. C.C. Gillespie, 1970)

Estimate 2: Fiziki — biograficzeskij sprawocznik (Yu.A. Khramov, 1983)

for the authors, the number of physicists–authors comes out to be slightly below 1200.

Yet another check is provided by the address book [5] for 1905. The total number of physicists' names listed there is 1290. On the one hand, quite many of those were high school teachers, and on the other hand the list is obviously incomplete because not all physicists provided their personal data for publication. However, one finds there also some names of academic physicists from several countries (Brazil, Chile, Greece, Peru, Turkey, Uruguay), which were not included in the two estimates mentioned above. Taking those additional names into account one may say that there were 1100 physicists active in 1900.

It is interesting to compare this estimate with the number of astronomers, published by O. Struve and V. Zebergs [6]. From the *Astronomisches Jahres-*

bericht, a bibliography of astronomical publications, they counted that there were about 1800 active astronomers in 1900. Unexpectedly, this number is significantly higher than that of active physicists. One explanation may be that astronomical publications in 1900 included a large proportion of short observational notes by the amateurs.

Small as the community of physicists had been in 1900, it included a considerable proportion of important researchers. Sir Brian Pippard [7] used a modern biographical dictionary [8] to estimate the number of physicists who were active in 1900 and remembered for their contribution to physics to have their biographies selected for the list of fame. An independent estimate by the present author, based on another biographical dictionary [9], yielded very similar result for the number of "top" physicists of 1900 (see the table). It appears that as much as about twenty percent of all physicists active in 1900 left lasting contributions to our science.

It is clear that there is much smaller proportion of "top" physicists in 2000 compared to that in 1900.

At the turn of the twentieth century Germany, Great Britain and France were the world leaders in physics. German physics community, the largest in the world, included such well known men as Max Abraham, Paul Drude, Friedrich Kohlrausch, Philip Lenard, Otto Lummer, Walter Nernst, Max Planck, Ernst Pringsheim, Wilhelm Conrad Röntgen, Heinrich Rubens, Emil Warburg, and Wilhelm Wien. Britain had famous William Thomson (Lord Kelvin), and also William Crookes, James Dewar, Joseph Larmor, Oliver Lodge, John Poynting, George Stokes, William Strutt (Lord Rayleigh), and

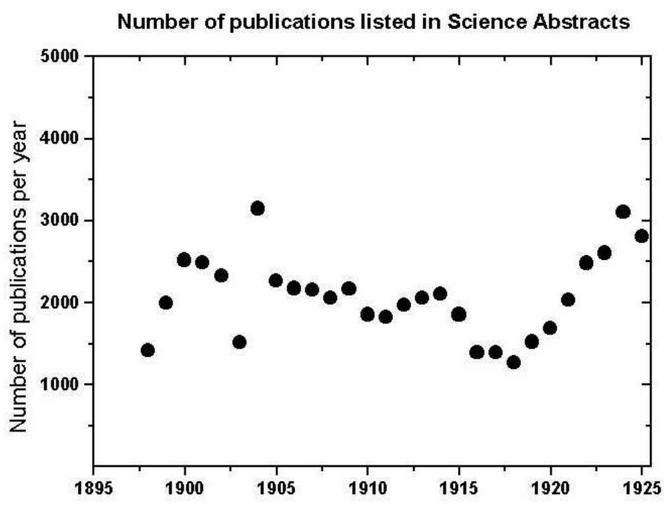

Fig. 2. Papers on physical sciences published between 1898 and 1925

SUBJECT INDEX.

To facilitate reference to any desired subject, the Index is divided into the following sections arranged alphabetically. If any of these are absent this may be taken as an indication that no Abstracts dealing with those particular subjects have been included in this volume.
The numbers refer to Abstracts, those in italics referring to References.

In General Physics:—Apparatus and Instruments (physical, excluding electrical, descriptive); Astronomy; Elasticity; Gravity; Measurements; Meteorology, &c.; Miscellaneous; Surface Tension; Theories.

In Light:—Absorption (light and heat); Dispersion; Interference; Measurements; Miscellaneous; Phosphorescence and Fluorescence; Photography; Photometry; Polarisation; Rays; Reflection; Refraction; Spectra; Vision; Zeeman Effect and Radiation in a Magnetic Field.

In Heat:—Absorption (light and heat); Conductivity (thermal); Critical Points and Constants; Dilatation; Freezing-, Melting-, and Boiling-Points; Gases and Vapours; Measurements; Miscellaneous; Specific Heat and Latent Heat; Temperature; Temperatures (high and low); Thermodynamics; Vapour Pressure.

In Sound:—All Abstracts referring to this subject have been indexed under *Sound*.

In Electricity and Magnetism:—Absorption; Alternate Current Research; Apparatus and Instruments (descriptive); Capacity (electrostatic); Conductivity and Resistivity; Dielectrics; Discharge in Gases and in Vacuo; Induction; Induction (self and mutual); Measurements; Medical Electricity; Miscellaneous; Oscillations and Waves; Polarisation (electric waves); Polarisation (electrolytic); Resonance; Static Electricity; Terrestrial Magnetism and Electricity; Thermo-Electricity and Thermo-Magnetism.

In Chemical Physics:—Absorption; Batteries (primary); Batteries (secondary); Chemical Equilibrium; Dissociation and Ionisation; Electric Furnace Processes; Electrolysis (commercial); Electrolysis (except commercial); Electrolytic Analysis; Miscellaneous; Osmosis; Solution and Solubility; Vats and Cells (electrolytic).

In Steam Plant, Gas and Oil Engines:—Accessories (steam plant); Automobiles; Boilers; Condensers; Economisers and Feed Water Heaters; Gas Engines, Gas Producers, &c.; Miscellaneous; Oil Engines; Steam Engines.

In General Electrical Engineering:—Accessories and Appliances (electrical, excluding traction); Apparatus and Instruments (descriptive); Batteries (primary); Batteries (secondary); Equipment of Factories and Machine Tools; Insulation and Insulators; Miscellaneous.

In Generators, Motors, and Transformers:—Alternators; Dynamos; Miscellaneous; Motors; Rectifiers; Transformers and Rotary Converters.

In Power Transmission, Traction, and Lighting:—Accessories and Appliances (traction); Automobiles; Cables, Conductors and Wiring; Costs; Electricity Works (descriptive); Lamps (arc) and Arc Lighting; Lamps (incandescent); Miscellaneous; Power Transmission and Distribution; Traction (electric, by accumulators); Traction (excluding accumulator traction and descriptions of power stations); Traction (mechanical).

In Telegraphy and Telephony:—Telegraphy (excluding wireless telegraphy); Telegraphy (wireless); Telephony.

Supplementary Index of Works and Installations described in this Volume, p. 1099.

Fig. 3. Subject index of Science Abstracts of 1900

John Joseph Thomson. Physics in France was dominated by Henri Poincaré and had also Emil Amagat, Henri Becquerel, Marcel Brillouin, Alfred Cornu, Pierre Curie, Gabriel Lippmann, Eleuthere Mascart, Jean Perrin, and Polish born Marie Skłodowska-Curie. The United States had a large number of universities and physicists, but less well known names, apart from Josiah Gibbs, Samuel Langley, Albert Michelson, Henry Rowland, and Robert Wood. Of the smaller countries one should mention the Netherlands, which had Heike

Kamerlingh–Onnes, Hendrik Lorentz, Johannes Van der Waals, and Pieter Zeeman. One should also mention Ludwig Boltzmann and Roland Eőtvős of Austro–Hungary, Pyotr Lebedev of Russia, and Svante Arrhenius and Johannes Rydberg of Sweden.

Fig. 2 shows the number of physics papers listed in Science Abstracts between 1898 and 1925. As mentioned above, until 1903 Science Abstracts included electrical engineering. A closer look at the Subject Index of Science Abstracts (Fig. 3) reveals main topics of interest for researchers in 1900. The papers in physics proper had been classified into six main categories (percentages given in brackets): General physics (17.1%), Light (17.0%), Heat (10.7%), Sound (1.6%), Electricity and Magnetism (31.0%), and Chemical Physics (22.6%). One may see that the vast majority of published papers pertained to "routine" measurements in classical physics. Only about 2% of all papers published in 1900 concerned "new physics": the X rays and radioactivity.

3. Ist International Congress of Physics, Paris, 6–12 August, 1900

International meetings of scientists have a tradition of 140 years. The first to meet were the chemists. The First International Congress of Chemists took place in 1860 in Karlsruhe with about 140 participants from 12 countries [10]. The Ist International Congress of Mathematicians organized in Zurich in 1894 was an even smaller event since there were less than 100 participants.

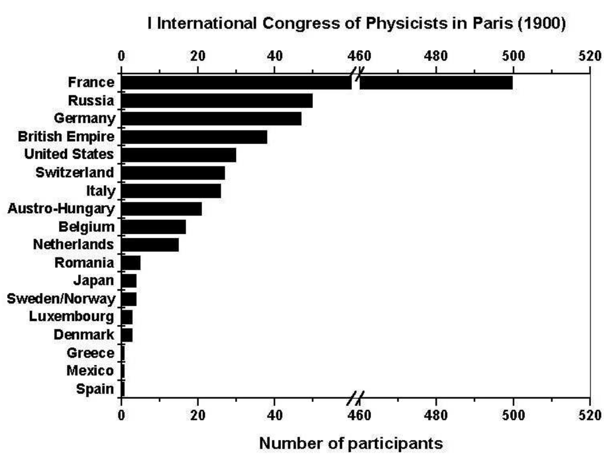

Fig. 4. Nationality of participants of the First International Congress of Physics in Paris.

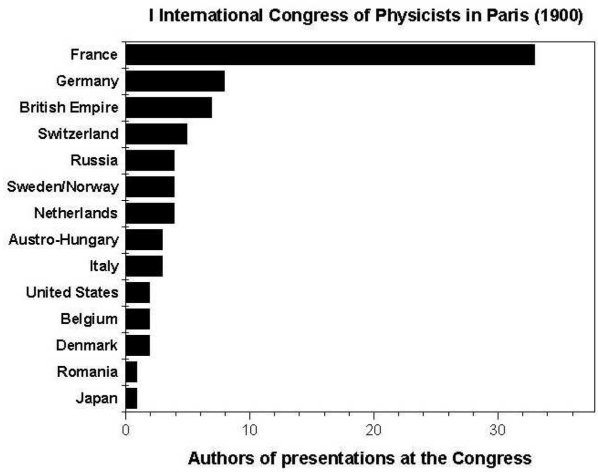

Fig. 5. Nationality of the authors of presentations at the First International Congress of Physics.

The physicists were late to convene at a world scale, but their first international meeting was a much bigger event, for it assembled more than 800 participants from 18 countries. The rules of the organization were well explained by E. Guillaume, the secretary of the Organizing Committee [11]: "The committee deliberately rejected the method of simply presenting personal memoirs, or notes on limited subjects, and concentrated all its efforts upon the preparation of a well-arranged summary of the actual state of physical science, in the branches in which, within the last few years, the greatest progress has been made, and the actual stage of progress of which at the end of the nineteenth century it was considered most important to investigate. Once the list of subjects was completed, the work was divided among the physicists who seemed best qualified to give a complete representation of their special subjects. This plan gave rise to a series of reports, many of which are works of a very high value, and which, in their entirety, constitute the most complete representation of any science at a given epoch yet made."

To facilitate the work the Congress had been divided into seven sections:

1. General problems and metrology
2. Mechanics and molecular physics
3. Optics and thermodynamics
4. Electricity and magnetism
5. Magnetooptics, cathode rays, uranium rays *etc.*
6. Cosmic physics
7. Biological physics

An introductory lecture to the Congress entitled: "Mathematical physics and experimental physics", was given by the famous French mathematician and physicist Henri Poincaré, who discussed relations between experimental physics and theoretical physics. Scientists must order — he said. "Science is build up with facts as a house is with stones, but a collection of facts is no more a science than a heap of stones is a house." He then compared experimental physics to a library. Theoretical physics arranges it and prepares the catalogue. It does not enrich it, but if it is well prepared it enables one to draw a greater profit from the former.

As remarked later [11]: "[Poincaré's] speech will no doubt be read and studied for a long time to come, and will remain one of the most perfect expressions of the state of mind of the masters of modern science."

Section 1 included the following presentations: Accuracy of measurements in metrology (Benoit), National laboratories (Pellat), Review of proposed systems of units (Guillaume), Interferometric measurements in metrology (Macé de Lépinay), Velocity of sound (Violle), Thermometric scales (Chappuis), Advances in pyrometry (Barus), Mechanical equivalent of heat (Ames), Specific heat of water (Griffiths), Standard of electromotive force (Gouy), Electrochemical equivalent of silver, copper and water (Leduc), Studies of level surface on earth and changes of gravity in a magnetic field (Eőtvős), Distribution of gravity on earth's surface (Bourgeois), Gravitation constant (Boys).

After the presentations of the most recent measurements in various chapters of physics, detailed attention was devoted to the complete metrological definition of standards and their legal definitions. Some resolutions had been passed, such as that recommending the adoption of the mechanical units (erg and joule) for the expression of calorimetric quantities. The Congress also supported the call for creating national physical laboratories in all countries to provide metrology services.

One may be surprised to find that topics such as measurements of the velocity of sound, the mechanical equivalent of heat, the specific heats, and electrochemical equivalents were still "hot" research topics in 1900.

The presentations in Section 2 included: Symmetry and elasticity of crystals (Voigt), Deformations of solids (Mensager), Solids under pressure (Spring), Constitution of alloys (Roberts–Austen), Formation of crystals at constant temperature (Van't Hoff), Calorimetry of liquids (Battelli), Statics of liquids (Amagat), Statics of mixed fluids (Van der Waals), Rigidity of liquids (Schwedoff), Determination of critical constants (Mathias), Critical refractive index (Galitzine), Osmosis (Perrin), Diffusion of gases (Brillouin), Capillarity (Van de Mensbrugghe), Melting and cristallization (Weinberg), Migratory deformations in solids (Guillaume), Hydrodynamical actions at a distance (Bjerknes), Specific heat of gases (Battelli).

Again, it is surprising to find that most "hot" research subjects of 1900 are now regarded as "closed" and usually discussed only in the general physics courses.

Section 3 included presentations on: Ether waves (W. Thomson), Distribution of spectral lines (Rydberg), Dispersion (Carvallo), Radiation of black bodies (Lummer), Radiation of gases (Pringsheim), Theoretical laws of radiation (Wien), Optical properties of metals (Drude), Velocity of light (Cornu), Radiation pressure (Lebedev), Kinetic theory of gases and Carnot principle (Lippmann), Advances in the theory of heat engines (Witz).

Following the discovery, by Balmer in 1884, of the numerical relation between wavelengths of hydrogen spectral lines, a number of other regularities were found in the spectra. The participants of the Congress listened to an excellent summary of these results given by Rydberg. The experimental results on black body radiation were presented by Lummer and Pringsheim, whereas the theoretical understanding was summarized by Wien. It is worth noting that Max Planck participated in the Congress but his revolutionary paper with "Planck's formula" appeared only on October 19, several weeks after the Congress. The participants could also listen to Lebedev, who presented his discovery, earlier that year, of radiation pressure, predicted by Maxwell.

Section 4 included presentations on: Propagation of electrical energy in electromagnetic field (Poynting), The ratio of electromagnetic and electrostatic units (Abraham), Velocity of electric waves (Blondlot and Gutton), Hertz waves (Righi), Radioinductors (Coherers) (Branly), Gaseous dielectrics (Bouty), Electrolysis and ionisation (Arrhenius), Hysteresis (Warburg), Contact electricity (Christiansen), Magnetic properties of matter (Du Bois), Magnetostriction (Nagaoka), Modifications caused by magnetization (Hurmuzescu), Transformations of carburized iron (Van't Hoff), Registration of variable currents (Blondel), Theory of electric cells (L. Poincaré), Electric arc (Lang), Polyphase currents (Potier).

Although the applications of electricity were almost entirely beyond the scope of the Congress there were nevertheless presentations in that Section touching subjects such as polyphase currents or electric arc. The main emphasis was, however, put on Hertzian waves and their application and on verification of the Maxwell theory involving the identity of luminous and electrical oscillations. The richness of precise data available at the time of the Congress on the velocity of light and of electric waves, and also on the ratio of electromagnetic to electrostatic units was reviewed in several presentations. As the instruments became more precise and the sources of error disappeared, Maxwell's theory was confirmed to a high degree of accuracy.

Section 5 included topics of ionisation and magnetooptics, which in the words of E. Guillaume, were at that time less well defined and could not be easily placed in the previous Sections. It was decided therefore to collect them in a special Section. It included a presentation by H. Lorentz of magnetooptics with special reference to Zeeman phenomenon. The speeches by Becquerel (Uranium rays) and by Pierre Curie and Marie Skłodowska-Curie on radiation from radium and polonium were given in a special large hall to accommodate all interested participants. For some listeners it was the first occasion to see the effects produced by newly discovered elements. Several hundred persons at a time could see the light radiated perpetually by radium. Other presentation in Section 5 were: Theory of dispersion in metals (Drude), Ionized gases (Villari), Cathode rays (Villard), Actinoelectric phenomena (Bichat and Swyngedauw) — such was then the name for the photoelectric phenomena. There was also a report entitled: Information on the structure of matter from studies of electric discharges in gases, prepared by J.J. Thomson, who did not come to Paris.

Section 6 included the following presentations: Physical structure of the sun (Birkeland), Solar constant (Crova), Comparison of light of the sun and the stars (Dufour), Atmospheric electricity (Exner), Study of northern lights (Paulsen), Ice and glaciers (Hagenbach), Oscillations of lakes (Forel and Sarasin). Terrestrial magnetism was omitted deliberately because of the plans to discuss it thoroughly during the meteorological Congress after the Congress of Physics.

The seventh Section included works related to biology. There were presentations on: Transmission of energy in organisms (Broca), Retina phenomena (Charpentier), Accommodation (Tscherning), Molecular phenomena caused by electricity in inorganic and living matter (Bose), Applications of spectroscopy in biology (Hénocque).

According to all observers the First International Congress of Physics had been a brilliant success. Many new thoughts have been born and many new friendships made or consolidated. The participants left Paris convinced of the great success and power of physics, which was found capable to explain so many complicated phenomena of the physical world.

4. Kelvin's clouds

On April 27, 1900, at the Royal Institution of Great Britain, Lord Kelvin delivered famous lecture entitled "Nineteenth Century Clouds over the Dynamical Theory of Heat". The expanded version of this lecture was published the following year [12]. In the introduction we find the statement often quoted as a quintessence of the *fin-de-siècle* confidence in classical physics:

"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. 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? The second is the Maxwell–Boltzmann doctrine regarding the partition of energy."

Kelvin carefully analyzed all arguments concerning cloud I. He even considered the renouncement of the doctrine that two portions of matter cannot jointly occupy the same space; ponderable bodies may then be assumed not to displace ether as they move, while each atom alters the density distribution of the ether within the space it occupies itself. This hypothesis could explain several phenomena but it is inconsistent with Michelson and Morley's experimental conclusion that ether in the earth's atmosphere is motionless relatively to the earth. "This cloud must be regarded as still very dense" — concluded Kelvin.

Concerning cloud II Kelvin performed elaborate numerical experiments with particles moving on a billiard table and bouncing off its boundaries. He found, for example, that when a particle moved on a triangular billiard table with angles of 97°, 53.5°, and 29.5°, and underwent 599 reflections, the ratios of the average components of kinetic energy in different directions to the actual kinetic energy were not uniformly 0.5, according to the Maxwell–Boltzmann doctrine, but varied between 0.5363 and 0.4637. From this and other similar experiments Kelvin concluded that the doctrine can be disproved, which allows "to lose sight of a cloud which has obscured the brilliance of the molecular theory of heat and light during the last quarter of the nineteenth century" [12].

The physicists of that time had a feeling that they had discovered almost all what was really there. It appeared that the atomic point of view combined with the electromagnetic field concept could provide the ultimate explanation. According to Hendrik Casimir [13], Peter Zeeman, who received Nobel prize in physics for 1902, enjoyed telling that he had been warned not to study physics: "Physics is no longer a promising subject; it is finished, there is no room for anything really new".

Well known also is the story of young Max Planck who wanted to start working for his Ph.D. in theoretical physics and was discouraged by Philip von Jolly more or less in these words: "Young man, do not try to spoil your life but better make another choice. Physics is so advanced that it will be finished very soon and you will have no future" [14]. And Albert Michelson in 1894 stated that: "The grand underlying principles have been firmly established … future truths of physics are to be looked for in the sixth place of decimals" [15].

On the other hand Kelvin, in spite of his enthusiasm concerning the dynamical theory of light and heat was well aware of the limitations of physics. In the emotional speech during his jubilee he did not hesitate to confess that [16]: "One word characterizes the most strenuous of the efforts for the advancement of science that I have made perseveringly during fifty five years, and that word is failure. I know no more of electric and magnetic forces or of the relation between ether, electricity and ponderable matter, or of chemical affinity than I knew and have tried to teach to my students of natural philosophy fifty years ago in my first session as professor".

5. New physics in 1900?

In 1910 Felix Auerbach published "Tables of the History of Physics" [17] which listed most important achievements, both experimental and theoretical, for every year since Antiquity until 1900. It is interesting to compare it with similar list published in 1983 by Yu.A. Khramov [18]. For the year 1900 Auerbach listed 69 items, and Khramov 17, of which only seven coincided with Auerbach's! The seven items, recognized as important by both authors, were:

(i) Planck's formula for blackbody radiation (his theory was not mentioned by Auerbach!),

(ii) verification of this formula by Rubens and Kurlbaum,

(iii) discovery of gamma rays by Villard,

(iv) discovery of the deflection of beta rays by electric field (Dorn, Becquerel),

(v) discovery that beta rays are negatively charged particles (Pierre Curie and Marie Skłodowska-Curie),

(vi) measurement of the e/m ratio for beta rays which yielded result very similar to that for cathode rays (Becquerel),

(vii) discovery by Lebedev of light pressure predicted by Maxwell's theory.

The comparison of Auerbach's and Khramov's lists for other years yield similar results. Most of the items listed by Auerbach have been forgotten or are now regarded as unimportant. However, his list did not include such items as: Planck's quantum theory, Rayleigh's radiation formula, Lenard's experimental results concerning the photoelectric effect, and Fabri–Perot interferometer, which from our present perspective are regarded as significant.

The measurement of e/m for cathode rays by J.J. Thomson has been included in Auerbach's list but it was not mentioned there that he discovered the electron. Present textbooks usually present an extremely simplified history of that discovery. As commented by Pais [19]: "J.J. Thomson discovered the electron. Numerous are the books and articles in which one finds it said that he did so in 1897. I cannot quite agree..."

Indeed, the discovery of the electron was a long and complicated process. The opinion of physicists in 1900 was well reflected in the review article by Ernest Merritt, professor of physics at Cornell University, then also vice-president of the American Association for the Advancement of Science. In his address at the New York meeting of the Association we find the following [20]:

"Among the branches of physical investigation that have recently shown special activity, few occupy a more prominent position at the present time than those that are related to the electrical discharge in rarefied gases. This is true not only because of the rapid development of the subject, but also because of the far reaching importance of the results, and the influence which they seem destined to exert upon widely different branches of physics."

Next Merritt gave description of experimental results and theories of the nature of the cathode rays, in particular of the surprising result obtained by Wiechert, Kaufmann and J.J. Thomson, that the e/m ratio for cathode rays is about thousand times larger than for the hydrogen ions. Thomson interpreted it as evidence for the existence of very light "corpuscules" with mass about one thousand times smaller than that of the hydrogen ion.

Then Merritt expressed his doubts: "The most serious reason for doubting the correctness of the values obtained for e/m ratio arises from the almost incredible velocity of the kathode rays. What right have we to suppose that ordinary electrical and mechanical laws are applicable to a particle moving at one-third the velocity of light? It appears to me that we have before us the most stupendous piece of extrapolation in the whole history of physics."

That much from Merritt. J.J. Thomson recollected that [21]:

"At first there were very few who believed in the existence of these bodies smaller than atoms. I was even told long afterwards by a distinguished physicist who had been present at my lecture at the Royal Institution that he thought I had been 'pulling their legs'. I was not surprised at this, as I had myself come to this explanation of my experiments with great reluctance, and it was only after I was convinced that the experiment left no escape from it that I had published my belief in the existence of bodies smaller than atoms."

To be sure, physicists in 1900 were discussing "electrons", but these were particles different from the electron, as we know it now. The name "electron" for the fundamental unit of electricity was coined by Johnstone Stoney in 1891. In 1896 Pieter Zeeman at Leyden made an important discovery of splitting of spectral lines in a magnetic field. His finding was followed immediately by a theoretical explanation provided by Hendrik Lorentz, who assumed that light was emitted by charged particles ("electrons") moving in the atom. Lorentz's "electrons" were both negatively and positively charged. From the observed splitting of the spectral lines Lorentz and Zeeman were able to calculate the e/m ratio of the "electrons", which was found to be very close to that for cathode rays, as determined by Kaufmann, Wiechert and J.J. Thomson. It was believed that "Lorentz's electrons" are numerous. As reported by Ernest Rutherford [22]: "The electron thus appears to be the smallest definite unit of mass with which we are acquainted. The view has been put forward that all matter is composed of electrons. On such a view an atom of hydrogen for example is a very complicated structure consisting possibly of a thousand or more electrons. The various elements differ from one another in the number and arrangement of electrons, which compose the atom."

Thomson did not use the word "electrons" but preferred to talk about "corpuscules", the term he used already in his first paper of 1897 [23]. The number of "corpuscules" in an atom was, as we have seen, expected to be very large. Only later Thomson devised a method to determine this number from arguments based on the scattering of X-rays and the dispersion of light in gases and also on the absorption of cathode rays and beta rays in matter. After 1910 it was generally accepted that the number of electrons in an atom is of the same order as its atomic number, although as late as in 1911, H.A. Wilson maintained that a hydrogen atom contained eight electrons [24].

As to the Thomson's trust in his "corpuscular" model of an atom, it is enough to quote his words of 1907 [25]: "The corpuscular theory of matter with its assumption of electrical charges and the forces between them is not nearly so fundamental as the vortex theory of matter, in which all that is postulated is an incompressible, frictionless liquid possessing inertia and capable of transmitting pressure. On this theory the difference between matter and non-matter and between one kind of matter and another is a difference between the kinds of motion in the incompressible liquid at various places, matter being those portions of the liquid in which there is vortex motion".

Thus we may understand why even as late as in 1910 Auerbach's tables did not contain reference to "Thomson's discovery of the electron in 1897". Only after Rutherford's nuclear atom of 1911 and Bohr's planetary atom model of 1913 did Thomson's work on cathode rays receive due credit and he was gradually accepted as the man who discovered the electron.

Let us now turn to the quantum theory, which the "folklore" history of physics places as one of the milestones in 1900. The October 19, 1900, paper of Planck, in which he presented the formula for the spectral distribution of blackbody radiation bore a modest title: "An improvement of Wien's spectral formula" [26]. Other phenomenological formulae for blackbody radiation were proposed in the same year by Lummer and Pringsheim, by Lummer and Jahnke, and by Thiessen. It is true that Planck's formula agreed best with the precise measurements performed by Rubens and Kurlbaum. On December 14, 1900, he presented another paper [27], which contained the derivation of the successful formula, based on the concept of quanta. This concept was so alien to classical physics that almost no one took it seriously. Albert Einstein was a notable exception when he developed in 1905 the idea of a corpuscule of light, later baptized "photon".

For many years Planck himself did not believe that the concept of quanta had any physical meaning. In his lecture during the First Solvay Conference on Physics in 1911 he declared firmly [28]:

"If one considers the complete experimental confirmation which Maxwell's electrodynamic theory obtained by means of the most delicate interference phenomena, and if one considers the extraordinary difficulties which its abandonment would entail for the entire theory of electric and magnetic phenomena, then one senses a certain repugnance in ruining its very fundamentals. For this reason, we shall leave aside the hypothesis of light quanta, especially since it is still quite early in the development of this notion."

As reported by Mehra [29], "Planck even felt tempted to see the separation or differentiation between physical and chemical phenomena. The atoms and molecules, and also perhaps the free electrons, move according to the laws of classical dynamics; however, the atoms or the electrons subject to a molecular interaction obey the laws of the theory of quanta. Physical force such as gravitation, electrical and magnetic attractions and repulsions, and cohesion, act in a continuous manner; chemical forces, on the other hand, act through quanta. The physical laws are of the same kind as allow the masses in physics to interact with each other to any extent, while in chemistry they can act only in definite proportions and vary in a discontinuous manner".

During the discussion after Planck's talk Sommerfeld expressed his belief that the hypothesis of emission quanta, as well as the initial hypothesis of the quanta of energy, should be considered more as a form of explanation rather than as physical reality.

Still later, in 1914, Planck, Nernst, Rubens and Warburg recommended to the Prussian Academy of Sciences to elect Einstein to full membership. Planck, who drafted the recommendation, apparently doubted Einstein's concept of the corpuscule of light, for he wrote [30]: "That he sometimes have missed the target in his speculations, as for example, in his hypothesis of light quanta, cannot really be held too much against him, for it is not possible to introduce really new ideas, even in the most exact sciences, without sometimes taking a risk."

Concerning the situation of quantum theory in Britain Arthur Eddington wrote in 1936 [31]: "Let us go back to 1912. At that time quantum theory was a German invention which had scarcely penetrated to England at all. There were rumours that Jeans had gone to a conference on the continent and been converted; Lindemann, I believe, was expert on it; I cannot think of anyone else."

It is also worth to know that Robert Millikan did not believe that Einstein's photoelectric effect formula had any physical meaning. In the same paper of 1916 in which he presented an experimental proof that this formula agrees with data, he used rather strong words as to its physical basis [32]:

"It was in 1905 that Einstein made the first coupling of photo effects with any form of quantum theory by bringing forward the bold, not to say, the reckless, hypothesis of an electromagnetic light corpuscle of energy $h\nu$, which energy was transferred upon absorption to an electron. This hypothesis may well be called reckless first because an electromagnetic disturbance which remains localized in space seems a violation of the very conception of an electromagnetic disturbance, and second because it flies in the face of the thoroughly established facts of interference. [...] Despite the apparent complete success of the Einstein equation, the physical theory of which it was designed to be the symbolic expression is found so untenable that Einstein himself, I believe, no longer holds to it."

Thus again it is not surprising that in 1910 Planck's quanta were not considered as important enough to be listed in Auerbach's tables.

Of the important discoveries that, as we know now, shook the fundament of the seemingly perfect edifice of classical physics, only radioactivity was regarded as exciting and important in 1900 [33]. The original texts cited in the present paper leave little doubt that the physicists active in 1900 were mostly very satisfied with classical physics and saw little need for "new" physics.

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