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Physics: trajectory in Chile

Claudio gutiérrez*; Flavio gutiérrez

ABSTRACT
This paper presents the development of Physics in Chile from the beginnings of the Republic until the year 1960, emphasizing the internal development of the discipline, the evolution of its conception and the transmission of its body of knowledge. This work faces the myth of the non-existent scientific tradition in Chile by showing in the case of Physics a long and sustained development. In this development we distinguish four stages of Physics: (1) As a chapter of Scholastic Philosophy; (2) As a discipline closely related to engineering and real-life problems; (3) As cultural science and base of a scientific view of the world; (4) As a discipline with its own problems, where research becomes a central part of its development. For the science historian the novelty is that this development follows a logic where the local parameters have strong influence as compared to those determined by the universal development of the discipline.

Key words: science, physics, engineering, Chile.

The study of solid science and the useful cultivation of talent
can not be separated from a nation's greatness and happiness.
It is not the number of men that constitutes the power of a nation
but its well arranged forces, and these come from the solidity and
depth of its knowledge.
(They have power) when they know how to calculate the relations
between things, know the nature of beings,
and acquire new strengths with mechanics […]
JUAN EGAÑA
Speech about Education, 1812.

PREFACE

There are at least three conceptual challenges to presenting a trajectory of physics as a discipline in a peripheral place like Chile, without turning the narration into a mere echo of the achievements and scientific developments of the center (especially Europe and the United States). First, there is the fixing of the concept of physics as used by its cultivators in Chile and the establishments of limits with close disciplines or with other disciplines that have been undistinguishable from physics in other times. As is natural, the meaning of the word *physics* has

changed with time and among different social groups, and it is necessary to determine if there is a continuity that makes it possible to talk about a trajectory. Secondly, one can propose an organizing in periods to give the presented material some coherence, to capture the landmarks of the development of this discipline in Chile, to contextualize it with the rest of Chilean history and with the discipline on a global level. And in the third place, linked with the others but typical of the historiography of scientific disciplines in the region, is the issue of how to face the myth of an inexistent scientific tradition, in this case physics. This myth gives the impression that in this region science is a product from far away that, at the most, has been copied and badly learned, and that in its great landmarks the local parameter serves as an object and is never a subject of this development. In this sense, scientific activity seems not to qualify as part of the country's development and history. The extreme of this thesis states that there has not been science or scientists in Chile up until a short time ago. This statement gives meaning to the work we propose here.

To delimit the concept of physics, we took as basis the discussion presented on this topic by the Chilean physicist and ex rector of the Universidad de Chile, Gustavo Lira, in his *Introducción a la Física General (Introduction to General Physics*. In our opinion this discussion fits the Chilean context perfectly. Due to the relevance this conceptual delimitation has, we reproduce the discussion extensively:

Physics as a science in the broader sense of the phenomena of organized life is composed by an extensive scientific material. In time *groups of characteristics and certain phenomena have been separating themselves from physics, and the study of these has developed into independent sciences.* Such are, for example, chemistry, mechanics, astronomy, mineralogy, geology, meteorology. However, it is significant that some of these branches have come in contact with the original trunk again, and scientific disciplines of great importance have developed, like chemistry physics, astrophysics, etc. Later on a series of sciences that pursue the *application of the scientific material of physics to humanity's practical needs*, separated from physics as well. One can say that among these are all the applied sciences that are at the base of material progress, like the resistance of materials, hydraulics, pneumatics, machinery, etc., all branches from applied mechanics: the techniques of vapor, of cold, electrotechnics with its branches (telegraphy, telephony, electric wiring, transmissions of potency, etc.) photography.

Physics conserve the pure scientific material that is the basis of those sciences, and from which new branches will detach themselves in the future, for use for man's needs.

This scientific material is normally divided in diverse sections according to the special character or the exterior or interior aspects of the phenomena these sections occupy themselves with. However, this division is artificial. In fact, it isn't possible to clearly separate classic parts of physics. Some of them tend to get confused in only one or they appear as intermediate parts placed on the limits of main divisions.

From another point of view, physics is divided in: *experimental physics and theoretical or rational physics.* Experimental physics contains the scientific material that is a result of experimentation and theoretical physics is the one that can be deduced from the phenomena themselves, from the hypothesis that can be formulated from them by induction and the laws of dependency one can establish from them. Again, one can see that this division lacks precision, because experimental physics constantly submits its proofs to theoretical physics, to the deductions drawn from laws of dependency and to the hypotheses that are established.

Certain aspects of a fact perfectly established by experience and using only reasoning in its most perfect form - mathematics – is also separated from different parts of physics. This scientific material constitutes mathematical physics, and there are different opinions as to its importance and use. Some chapters of mathematical physics are the theory of electricity, the theory of potential,

hydrodynamics, which, as we have said, are separate sciences with a development based on principles of experimental physics that are exclusively mathematical[1].

The second challenge is related with organizing the discipline's development in periods. We can first state that the development of physics in Chile has followed rhythms more dependent on the economic, social and cultural conditions of the country than on the development of the discipline on a "global" level (it would be more precise to say European and North American). In fact, the landmarks of the history of physics, as conceived classically, do not fit with the local developments, except on a very general level. For the development of the discipline on a local level, university developments, educational policies and economical theories have weighted as much or more than fundamental landmarks that arrange the classic history of physics in certain periods, like the appearance of thermodynamics, electromagnetism or quantum mechanics. According to this, we have divided the trajectory of physics in Chile in four periods: the first, in which physics is understood as a chapter of scholastic philosophy; the second, in which physics is completely indistinguishable from its applications, where "mathematics and physics" is a whole associated to engineering; the third, that corresponds to the identification of physics as an independent, autonomous and conceptual discipline, that gradually becomes independent from engineering, and plays a key role in education and the formation of a "scientific" concept of the world; the fourth period responds to the concept of physics as a discipline with its own problems, where investigation and creation become consubstantial parts of its development.

The third challenge, the persisting myth of the inexistence of a scientific tradition in the region, a thesis sustained particularly – though implicitly – by the new generations of scientists, made this work more difficult. This myth is based on a historical anachronism that extends to the past the criteria used today to delimitate science, and it complicates the process of looking for and evaluating the sources for the history of science in the region. A good example of this problem is the relationship and the roles that exist between foreign and national teachers hired in different stages. Thanks to their European training, the first ones arrived already qualified as scientists and were considered to be bearers of the latest advances of the discipline in Europe. This marked a strong slanting in the primary and secondary documentation, doubtlessly also influenced by the ranking society as a whole gave them as representatives of an "advanced civilization", in opposition to the locals that tried their hand at science. Balancing these factors adequately is one of the basic tasks to correct the well spread and inadequate application of only European cannons to judge American science in the diverse moments of its history without considering the local element.

Finally, some words about the temporary limits of this study. At the beginning of the 19th century a really independent activity began in Chile in relation to cultural and scientific matters. This is particularly so in the case of physics, as shown by the facts presented. We stop in 1960, with the symbolic limit of the creation of the Sociedad Chilena de Física (Chilean Society of Physics). The previous decade and those that follow mark the beginning of an era of an increment in professionalism of the discipline, and show a new stage of development that is much more documented and studied.

I. FROM SCHOLASTICS TO PHYSICS

A little after the first government junta, the founders of the republic committed themselves to found a great school destined to "give the fatherland citizens to defend it, direct it, make it

* Universidad de Chile. E-mail: cgutierr@dcc.uchile.cl

[1] Gustavo Lira, *Introducción a la Física General,* Santiago, Editorial Edugal, 1957, Section I.7 División de la Física, 6-8.

flourish and give it honor"[2]. This school became the Instituto Nacional (National Institute), inaugurated on august 10th 1813, that initiated its activities with 18 courses, one of them experimental physics directed by the priest José Alejo Bezanilla. Experimental physics and chemistry were taught in the class of natural sciences, next to botany, geography, economics, politics, pure mathematics and living languages. After 14 months the Instituto had to close its doors because of the Rancagua disaster, and remained closed during all the period of the Reconquista (Reconquest, 1814-1819).

Before the creation of the Instituto Nacional there were only sporadic activities in physics. Juan Martínez de Rozas, lawyer and PhD in civil and canonic law taught during three consecutive years (1781-3) experimental physics, besides scholastic physics, at the Colegio de San Carlos or Colegio Carolino. This was the first time experimental physics was taught in Chile[3]. Martínez de Rozas was a good friend of José Antonio de Rojas, who is known to have participated in 1781 in an early conspiracy, that of the three Antonios, to obtain the independence of Chile. Rojas wasn't only advanced in political matters: he also introduced some physics appliances in the country in those years, among them an electric machine with various accessories that afterwards passed on to the Instituto Nacional. There is no evidence of Martínez de Rozas using the physics apparatus of his friend during his classes. We do know that Rojas earned himself the title "wizard of the Colony" for the miracles he performed with his electric machine. Other activities were the classes the Spanish engineer Agustín Cavallero held in the Academia de San Luis (1799) oriented to military problems, where topics of static, dynamics, hydrostatics, hydraulics and optics were touched upon. In this same Academia de San Luis, Manuel de Salas organized the first physics and natural history study. In 1813, the Colegio Carolino and the Academia de San Luis were annexed to the Instituto Nacional with all its assets.

Once the Instituto was reopened in 1819 after the victory of Maipú, Bezanilla himself took on the course of physics again, now as part of philosophy, and followed mainly the text by Altieri, consulting Brison too[4]. By that time physics was divided in two parts: general and particular physics, as the teacher Diego Torres said in his speech when he first joined the Faculty of Physical and Mathematical Sciences[5]. The first, general physics, comprised cosmography, physical geography and some natural history. The second, particular physics, comprised physical phenomena and their causes (as they were understood in 1874, year of his speech). Bezanilla gave his classes in Latin. A witness of that time tells that "when they had philosophy in Latin, a teacher taught them under the name of physics, about a hundred more or less meaningless axioms about equilibrium, the falling of bodies, light, sound, etc. The students learned these axioms by heart and in Latin"[6].

Around this time, the group in power was very interested in incorporating science to the development of the country. One of the first measures in this direction was the government's hiring of European "learned men" to attend to the educational needs and write down the first land registry of national riches. The interest in science also motivated the founding in 1823 of the Academia Chilena (Chilean Academy), dependent on the Instituto Nacional, with three sections: Moral and

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[2] Domingo Amunátegui Solar, *Los primeros años del Instituto Nacional,* Santiago, Imprenta Cervantes, 1889, 85.

[3] *Ibidem*, 540.

[4] Diego Torres, "Elogio del doctor José Vicente Bustillos; Reseña de la enseñanza de la física y química en Chile", *Anales de la Universidad de Chile,* Santiago, April 1874, 289.

The texts mentioned are: Altieri, Laurentio, *Elementa philosophiae in adolescentum usum. Tomus tertius in quo traduntur elementa physicae particularis.* Rinaldi, Ferrariae. MDCCLXXI [1771]. A text of 600 pages in Latin that contains an ample treatment of astronomical physics and optical physics with fascinating figures, and Brisson, Mathurin-Jacques, *Traité élémentaire aux principes de physique, fondés sur les connaissances les plus certaines, tant anciennes que modernes, et confirmés par l'expéérience,* Paris, Montard, 1789.

[5] Loc. cit.

[6] Quoted in Ricardo Donoso, *Las ideas políticas en Chile*, México, Fondo de Cultura Económica, 1946. 328.

Political Sciences, Physical and Mathematical Sciences, Literature and Arts. The founder of the Chilean squad, Manuel Blanco Encalada, the Spanish physician Manuel Grajales and the French engineer Carlos Ambrosio Lozier were some of the teachers of the second one. Lozier became rector of the Instituto in February 1826 and performed a radical reform to eliminate the last residues of colonial teaching. Among other things, this reform implied changing almost all the teachers. Priest Bezanilla was replaced by the canon Puente, head of the mathematics department in the Instituto since its founding. He in turn left his position together with Lozier who had to resign to the rectory in September of the same year, among other reasons, because of the strong opposition of the illustrated society to such reforms.

In 1827 the Spanish engineer Andrés Antonio Gorbea took on the teaching of the course of experimental physics. One could say that the first serious intent at developing physics in Chile began here. Gorbea came in Chile the year before hired by the government as a mathematics teacher for the Instituto Nacional. He had studied mathematics and engineering in Spain and perfected his knowledge of physics in France studying with Louis Joseph Gay-Lussac, the famous French chemist and physicist. In 1828 the first book of physics was published in Chile under the direction of Gorbea, a compendium and translation – by Gorbea himself – of the experimental physics of Biot, a work that Lozier had managed to introduce during his brief position as rector[7]. Despite Gorbea´s reputation, few students came to his classes, and those who did did it out of mere curiosity, because the study of this course wasn't obligatory; so there was no advantage to make out of his course[8]. Gorbea is considered to be the founder of the teaching of mathematics (in its modern sense) in Chile, and the father of Chilean engineering. In physics he is also remembered for teaching the first course of rational mechanics in Chile in 1850.

II. PHYSICS AS A SCIENCE OF REAL-LIFE PROBLEMS

Despite the little interest in the study of physics, the intellectuals of that time highly valued this discipline as a useful tool for the development of the nation. Andrés Bello, the Venezuelan scholar who became the first rector of the Universidad de Chile, said in an article published in *El Araucano* on January 21st 1832: "The main professions in Chile are agriculture, mining, commerce and law: they all demand a lot of knowledge of physics, and it is necessary to teach them in preparatory education"[9]. As they came from him, these words didn't go unnoticed, and this criterion of usefulness marked the development of physics until the second half of the 19th century.

2.1The Colegio de Coquimbo

In 1838 the engineer in mining Ignacio Domeyko was hired in Europe to take on the teaching of mineralogy in the Colegio de Coquimbo. Domeyko, of Polish origin, had studied in the School of Mines of Paris where he bought tools and instruments of the latest generation to mount a chemistry laboratory in Conquimbo and a physics and mineralogy study to do analyses and other types of investigations. A special building had to be built to install the numerous tools that came

[7] We haven't had access to this translation. However, in the Nacional Library there are the following versions of the book by Jean-Baptiste Biot (1774-1862): *Physique expérimentale,* Paris: [s. n.], 1824, 2 v.; 24 cm. *Precis élémentaire de physique experimentale,* 13e éd. Paris: Impr. Leblanc, 1824, 2 v.: il.; 20 cm. *Tratado de física experimental, translated by Fco. Grimaud,* Madrid: [s. n.], 1826, 4 v.; 23 cm. and *Física experimental,* Paris: [s.n.], 1828, 4 v.; 22 cm.

[8] Torres, 289.

[9] Amunátegui, t. I, 496 Here physics has a double meaning, one broad one of the phenomena of organized life (as Lira states in the paragraph quoted at the beginning of this article) and another one in the technical sense of the concept of "physics" in that time. Bello –who knew the experimental physics of his time well– seems to play with this duality to foment its technical development without offending the mentality of the majority.

inside of thirty large boxes[10]. There were no programs and the boys, all miners´ sons didn't have the slightest knowledge of the basic sciences needed for mineralogy, Domeyko said. They had to begin with experimental physics to stimulate the interest in the usefulness of this science in mineralogy. In three months he exposed the basic principles of this science. In January 1839 a group of his best students explained in a public exam the structure and functioning of the barometer, thermometer, aerometer, the construction of pumps, the power of steam, and did experiments with the electric machine, the pneumatic machine and other elements of the new laboratory. Domeyko said the public was pleased, but unsatisfied for not having heard the slightest mention about mineralogy. In short, Domeyko installed the first physics study in Chile and gave the first classes of experimental physics. He taught eight years in the Colegio de Coquimbo and moved to Santiago in 1846, leaving three of his best disciples to succeed him in Coquimbo. They had perfected their studies of mineralogy in France, financed by the Chilean government. Physics began to be useful to the development of mining in Chile, as Bello wanted.

2.2 The Instituto Nacional

Meanwhile, in the Instituto Nacional the science of physics was in a deplorable state, both in university as in preparatory (secondary) school. In his annual report, in April 1845, the rector Antonio Varas expressed: "Physical and natural sciences have been the most unlucky ones among us. While for the rest of the disciplines courses have been organized and there is a more or less acceptable number of students, physical and natural sciences are still in their beginnings"[11]. The next year in the same ceremony, the new rector Francisco de Borja Solar said: "Now it's my turn to talk about the mathematical and physical sciences, and I can only regret the sad and deplorable state they're in". To improve them it was necessary to struggle not only against the lack of instruments, studies and professors, but also against the incomprehension of its importance and incidence in the development of the country. Faced with this reality, Domeyko was called in 1846 to repeat his successful experience in Coquimbo in the Instituto Nacional. In April of the following year he started teaching physics, chemistry and mineralogy, and began installing laboratories for these subjects. Very soon, with untiring zeal, he made an excellent translation of the physics text by Claude Pouillet, and published it in 1847[12]. He proudly wrote in the prologue that his work "that by order of the Ministry of Public Education has been published to serve as a text for teaching physics in the Institute of Santiago, is the same by which its author the noted Pouillet teaches this subject in the Sorbonne"[13].

Domeyko´s course was aimed at professional teaching and the students that followed studies related to engineering were the only ones who got any use out of it. He taught it in the *University Section* of the Instituto, under control of the Faculty of Physical and Mathematical Science through a delegate. It was, therefore, a university course. We will come upon this development later on.

In the *Preparatory Section* of the Institute, that is to say, in the course of humanities that was a prerequisite to access the superior classes and lasted six years, physics was taught in the third year. This course opened in 1851 and was taught by Antonio Ramírez, who had a little book printed

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[10] Ignacio Domeyko, *Memorias*, 2 volumes, Santiago, Edititorial Universitaria, 1994, 188.
[11] Torres, 291.
[12] Eulogio Allendes,"Discurso de incorporación a la Facultad de Ciencias Físicas y Matemáticas, Anales de la Universidad de Chile", Santiago, October 1859, volume XVI, 1974. Allendes, as a student of Domeyko, was witness to that process. Claude-Servais-Mathias Pouillet was a French physicist, professor at the Polytechnic School and at the Sorbonne, and invented the compass of tangents and other meteorological devices.
[13] The translation by Domeyko is: *Elementos de física esperimental i de meteorolojia: obra en su mayor parte compendiada i reimpresa de la traducción española del tratado de física de Pouillet, con varias correcciones i adiciones sacadas de la cuarta edición del mismo autor, para la enseñanza de la física en el Instituto Nacional e impresa por orden del Gobierno*, 2 volumes, Santiago: Impr. del Progreso, 1848.

for his classes based on the Physics by Avendaño[14]. His teaching lacked experimentation because there was no study for this; the only apparatus was an old electric machine (perhaps donated by José Antonio Rojas?). The first physics study for elemental teaching was installed in 1857, when the engineer in mining José Zegers Recasens took over the course. Things weren't better in the provinces.

2.3 The Escuela de Artes y Oficios

The Escuela de Artes y Oficios (School of Arts and Technical Professions) was founded in 1849. Its director, the French engineer Julio Jariez, taught a course of Industrial Mechanics for the students of the higher courses. This course began with elemental physics: static, dynamics, falling of bodies (these laws were verified with the machine of Atwood), and movement of projectiles, inclined plane, simple machines and other subjects destined to establishing industrial machinery. The second part consisted of mechanics of liquids and gases and its application to hydraulic pumps and irrigation channels. It continued with heat, a steam machine, motors and factories, like grain mills, sawmills, cotton plants, paper mills, forges, etc. The studies continued with the construction in the school's workshops of instruments and machinery for industrial, agricultural and mining use, which were sold later on. As we see, the spirit and practice followed in detail the ideas of Bello´s article of 1832 about science as a useful science applied to industry, agriculture and commerce. Jariez published two volumes about this subject[15]. The Escuela de Artes y Oficios continued this tradition, particularly when José Zegers was named director in 1863. He also taught physics, and we shall talk about him later on.

2.4 Consolidation of experimental physics

The practice of Experimental Physics began to establish itself in the second half of the 19th century.

In 1858 there were 14 schools in Chile that taught physics: eleven boys´ schools and three schools for girls, and the same number of teachers. The total number of students was 272, 164 boys and 108 girls, according to a report by the Universidad de Chile[16]. This report shows that Domeyko taught physics in the University Section of the Instituto to nine students of between 18 and 22 years of age; General José S. Aldunate taught physics in the Military School to six cadets, and José Zegers taught the fifth year of Humanities three days a week.

José Zegers took over the course of physics in the Instituto Nacional in October 1857. This young teacher, a disciple of Domeyko, took care to obtain instruments to mount a study so as to

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[14] *Elementos de Física Experimental (sacado de la obra del Sr. Abendaño)*, Santiago, Imprenta de Julio Belin y Cía, 1852. Quoted in Torres [5], p. 295. and by Patricio Martens, *Las Ciencias Exactas, un aporte al desarrollo del país. Desarrollo de la Física en Chile*, Cuadernos de la Universidad de Chile, No 2, Santiago, 1983.

[15] Julio Jariez, *Curso Completo de Matemáticas, Física y Mecánica aplicadas a las Artes Industriales,* 6 volumes, Santiago de Chile, El Ferrocarril, 1860. Industrial Mechanics is covered in volume V and VI, with the following contents: Dynamics, Static (including gyration and resistance of wood and metals); General Considerations about machines in movement; Fluids (ends with pumps, irrigation channels, some machines to elevate water); Heat (culminates with steam machines); Calculus and establishing motors (pumps, hydraulic wheels, steam machines, mechanisms); Notions about movement and establishing large factories (grain mills, sawmills, blowers; cotton plants, paper mills, oil mills, forges, channel cylinders used for the production of steel).

[16] "Informe sobre educación publicado por la Universidad de Chile", *Anales de la Univ. De Chile*, t. XV, 1858, 292 and next.

give his lessons the experimental character they deserved; but it was far from being a complete study. Doubtlessly, he left his mark when he chose the classic book by Ganot as a guiding text, which was used for many years afterwards at the institute. The *Traité Elémentaire de Physique Expérimentale et Appliquée et Météorologie* by Adolphe Ganot was during almost all of the second half of the 19th century the guiding text for physics in all the major universities of Europe and the United States[17]. Zegers also greatly promoted the diffusion of physics: he published studies about electricity and the new barometers; about mechanics and the teaching of experimental sciences. He taught until May 1865, when he was replaced by Diego Antonio Torres. He was also a physics teacher at the Military School and – as we have seen – at the school of arts and technical professions. Later on he was General Essayist of the Casa de Moneda (House of Government) and he also occupied different public positions.

Soon, other names came up in this area. Diego Antonio Torres was an enthusiastic teacher of physics. In April 1874 he was named academic member of the Faculty of Physical and Mathematical Sciences for his merits as a chemistry and physics teacher, in succession of José Vicente Bustillos, who had died a little earlier. In his incorporation speech – that we have already quoted – he tells a brief history of the beginnings of physics and chemistry in Chile. He completed the physics study initiated by José Zegers for the classes of elemental physics at the Institute, turning it – as told by him – in one of the best in the country, thanks to the wholehearted support of Diego Barros Arana, at that time rector of the establishment and visionary promoter of the teaching of science in secondary education. "Don Diego," Torres tells us, "not only invested the funds this institution could use to buy instruments, but he also took sums from his own pocket to buy the valuable apparatus he gave to the Institute"[18]. By then (1874) several schools of the provinces also had good physics studies, among them the School of Coquimbo, the state schools of Copiapó, Concepción, Talca and Valparaíso. The teaching of experimental physics started to take shape throughout the country, and it consolidated with the founding of the Instituto Pedagógico (Pedagogical Institute) in 1889 and the training of teachers in this subject. Dr. Alberto Beutel took on the professorship of Physics at the pedagogical institute; he was also in charge of Chemistry and Mineralogy. His specialty was chemistry, so he did not determinedly promote physics. "His classes were extremely descriptive; they were a kind of lesson of things, according to his students´ testimonials"[19].

III. PHYSICS AS A BODY OF KNOWLEDGE

Around the turn of the 19th to the 20th century a new stage in the teaching and conception of physics began, for which Wilhem Ziegler and Luis Ladislao Zegers were responsible. Let us remember that physics – and other sciences – were basically considered as a useful knowledge for the material development of the country, which could help mining, industry, agriculture, medicine and engineering. During almost all the 19th century, the teaching of physics was directed to the

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[17] The first edition (in French) is from 1851. The first English edition is from 1863. The version of 1859 is at the National Library, and it is probably the one used by Zegers :
Adolphé Ganot (1804-1887) *Traité élémentaire de Physique expérimentale et apliquée et de météorologie* / Adolphé Ganot. 8ème éd., Paris: [s.n.], 1859. (Description 824 p.; 20 cm.). The text was divided in 11 books that covered: Matter, Forces and Movement; Universal Attraction, Gravity, particular properties of solids; of liquids, of gases, acoustics, heat, light, magnetism, static electricity, dynamic electricity, and meteorology and climatology.
For the importance of Ganot´s text on a global level, see Charles H. Holbrow, "Archaeology of a Bookstack: Some major introductory physics texts of the last 150 years", *Physics Today,* March 1999, 50-56.

[18] Torres, 295.

[19] Arturo Valenzuela Radrigán, "La Enseñanza de la Física en relación con la Facultad de Filosofía y Educación", Facultad de Filosofía y Educación, *Conferencias conmemorativas de su Primer Centenario, 1843-1943,* Santiago, Imprenta Universitaria, 1944, 121-126.

description, understanding and handling of the instruments that each sector needed in its practice, and hence concluded with lessons useful to each sector, but without inner consistency. In elemental education, because of the lack of specialized teachers, the classes were taught by some professional with a vocation for teaching (and sometimes even without), some secondary school graduate, and in the provinces, even by some amateur.

3.1 Physics in the Instituto Pedagógico

Dr. Wilhem Ziegler succeeded Beutel in the Instituto Pedagógico; the former arrived in Chile from Germany on May 27th 1903 to work at the institute. From then on the teaching of this discipline took on another direction. From the beginning, Ziegler had the intention of teaching physics in Chile analogous to how it was done in German institutes and universities of that time; that is to say, as a unitary discipline dedicated to explaining and searching for fundamental laws, not necessarily related to chemistry or mineralogy, meteorology or the betterment of electrical or mechanical devices[20]. Physics would now be taught as a conjunct of enunciates that could be empirically be compared and arranged in a hypothetical deductive system. This meant that it had to be taught as an experimental discipline, with the indispensable use of a laboratory and mathematics. This was a radical change from the concept of physics as a useful knowledge. Ziegler himself states it like this in a study published in 1906: "After two years of detained observation, I've been able to form myself a clear idea of the current state of the teaching of physics in Chile and I'd like to express my opinion about its defects and the possibility to change them. The main defect of this teaching, in my opinion, is that there is an absolute lack of ultimate connection between the different parts. The teachers isolate the different phenomena; we should call the physics classes "lessons of things". With this method, as is natural, the student gets a completely false idea of this course of knowledge"[21]. He attributed this to the fact that "the larger part of teachers has no good grasp of the subject they have to teach" and concluded: "here lies the root of all evil and this can only be destroyed preparing the physics teachers in a more solid manner". He started this task by building a physics laboratory in 1903. After untiring work, he broadened the building of the Pedagogical Institute. There he had the space to present a real class in experimental physics. But for physics to be a fruitful course in teaching – he said – it has to be studied with the help of mathematics, which gives an inner connection to the apparently isolated phenomena. During the first years of the Pedagogical Institute, when the study of teaching lasted three years, the teaching of physics was limited to experimental physics. In 1908 this study was increased to four years. With the collaboration of Richard Poenisch, a PhD in mathematics hired by the government in Germany in 1889, he arranged a solid basis in mathematics for his students. This would prepare them to follow the first course in rational mechanics taught in the Pedagogical Institute in 1912, which was the basis for the disciplines of theoretical physics.

The teaching of physics at the Pedagogical Institute was also directed towards the programs of the state secondary schools. With this end in mind, Ziegler created a course of Special Methodology of Physics. One of his assistants tells[22] that he was so preoccupied with the teaching of this subject in the state secondary schools, that every time one of these schools was founded, Ziegler ran to the Ministry of Education to demand the set up of a physics study. His work *Física Experimental (Experimental Physics)*, written in collaboration with Luis Gostling as a text for

[20] Sobre esta concepción de la física en esa época, ver por ejemplo, Lewis Pyenson, "History of Physics", en R. G. Lerner, G. L. Trigg, *Encyclopedia of Physics*, Second Edition, VCH Publishers, Inc, New York-Weinheim-Cambridge-Basel, 1990.

[21] Wilhem Ziegler, *Ideas generales sobre la enseñanza de la física en Chile*, Santiago, 1906, 21 pages. Quoted in Sandra Arrese, Sergio Prenafeta, *Enciclopedia Temática de Chile*, volume 10: Ciencia y Tecnología IV Sociedad Editora Revista Ercilla Ltda., Editorial Lord Cochrane, Chile, no date, 44-45.

[22] Professor Raquel Martinolli, Chief of the Laboratory (Recalled by Flavio Gutiérrez.)

secondary schools, reached its 16th edition in 1959. These texts (three in total) unified the teaching of physics in the state secondary schools, and changed those "lessons of things" for authentic classes on experimental physics[23].
His successors in the professorship of the Pedagogical Institute were first Diego Berendique and later Arturo Valenzuela. They had the difficult task of continuing and deepening their teacher's work that began to open up towards scientific investigation in the 1940s.

3.2 Physics in the School of Engineering

Now is the time to go back to the teaching of physics in the University Section, where we left Domeyko with his physics course as basis for the study of mineralogy, a professorship he maintained for almost twenty years. Although Domeyko wasn't a true physics teacher, his classes, always experimental, managed to awaken the vocation for physics in some of his students, among them José and Luis Ladislao Zegers Recasens. We already met with the first as a physics teacher at the National Institute, the School of Arts and Technical Professions and the Military School. The second, a mining engineer just like his brother, succeeded Domeyko in his university professorship.

Luis Ladislao Zegers received a government scholarship in 1875 to go to Europe to "study physics with as much development as possible, listening to the lessons given by the knowledgeable European professors", and more importantly, practically working with them in the laboratories. The government also commissioned him with studying the latest advancements of the application of electricity to the telegraph, and above all the distribution of drinking water in the big urban areas. He deepened his studies of physics at the College of France. In his report to the government he writes: "The time has come, Mr. Minister, for us to do for physics in our country, what has already been done for mineral chemistry". Clearly, he refers to Domeyko. Zegers is perfectly conscious of the importance physics has taken: "In this century, science owes its most beautiful discoveries to physics; it is the basis of the highest scientific investigations, and at the same time the most powerful auxiliary of industry. [..] Physics is today a science, without which no investigador could take one single step. It is the basis of the knowledge of engineers, physiologists, industrialists"[24]. Zegers is the fist in Chile who calls the attention of the academic world on the characteristic of physics as an autonomous discipline, especially on its facet as an especially experimental science. That is why he spent a large part of his scholarship doing laboratory work next to the best French teachers, among them Mascart, successor to Regnault in the Laboratory of the College of France. His great concern before going back to Chile was the acquisition of instruments to equip the laboratory of the University, particularly "instruments of precision that must be an indispensable part of any laboratory worthy of that name", he stated in his report to the government.

Luis Zegers was a brilliant teacher and an outstanding professional, "the most important figure the history of physical sciences presents us" in Chile towards 1910[25]. Zegers, a personal friend of the great inventor Thomas Alva Edison, had ample interests and an extensive oeuvre. His publications included from essays about mechanical energy transported by electricity, to a study about determining the richness of sugars through optical procedures, to an essay about metric and

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[23] W. Ziegler, L. Gostling, *Física Esperimental*, Imprenta Ehrhardt Karras, Halle A/S., 1913. volume I, Mecánica (Cuerpos sólidos, Cuerpos líquidos, Gases). volume II, Física Molecular (Calor, Magnetismo, Electrostática, Galvanismo, Electrólisis, Electromagnetismo, Teoría de Ondas, Acústica, Optica). With minor modifications, the text was edited in Chile in 1924. W. Ziegler, L. Gostling, *Física Experimental, Texto aprobado por el H. Consejo de Instrucción Pública*, Santiago, Edit. Nascimento, 1924. It was now divided in three volumes: Volume I: Mecánica; Volume II: Física Molecular, Teoría de Ondas, Acústica, Calor y Magnetismo; and Volume III: Electrostática, Electricidad dinámica, Optica.

[24] Luis L. Zegers, *La Física en la Universidad de Chile, nota pasada al señor Alberto Blest Gana, Ministro de Chile en Francia*, París, Tipografía Lahure, 1876.

[25] Jorge Huneeus, Cuadro Histórico de la Producción Intelectual de Chile, Santiago, Biblioteca de Escritores de Chile, 1910, volume I.

thermometric units in Chile. His book about *The transit of Venus around the Sun* (1882) earned him the clapping of the academic hands of France. However, what gave him his deserved fame and locates him between the pioneers of physics in Chile, was his feat of reproducing in his laboratory Roentgen's discovery of X rays (December 1895) a mere three months later (March 22 1896). With Professor Arturo Salazar, they made surprisingly clear radiographies of Zegers´ left hand. It was the first radiography in Latin America and Spain, the second in America and the seventh in the world[26]. With the same promptness, he also divulged the first investigations by the Curies[27]. In 1902-3 he published his *Tratado Elemental de Física General (Elemental Treaty of General Physics)* in three volumes[28], the first systematic text on physics made in Chile, and predecessor to the successful *Física Experimental (Experimental Physics)* by Ziegler and Gostling. His academic and scientific merits earned him the distinction of Member of the French Society of Physics.

Zeger was succeeded in the professorship of Physics by the engineer Gustavo Lira Manso, who later became Dean, Rector of the University during a brief period, and Minister of Education in 1931. Lira Manso wrote and published a voluminous treaty of *General Physics* as text for his professorship[29].

IV. TOWARDS PHYSICS AS A CREATIVE PROCESS

At the beginning of the 20th century physics in Chile gradually abandoned its merely utilitarian sense and was valued more and more a transformation in a theoretical discipline of scientific creation. On one hand, the teaching of physics was consolidated with the training of teachers at the Pedagogical Institute of the Universidad de Chile; on the other, with the training of engineers at the Faculty of Physical and Mathemarical Sciences of the Universidad de Chile, and later in other universities, particularly the Universidad Católica de Chile, the Universidad de Concepción and the Universidad Técnica Federico Santa María. On another level, the industrial applications of physics flourished. One can get a good idea of this balance in the reports of the Physics Section of the First Pan American Scientific Congress, celebrated in Santiago in December 1908. For example, Albert A. Michelson sent a work about the recent progress of spectroscopy, Luis Zegers exposed about industrial experiments of copper by electrolysis and Arturo Salazar about Weston batteries and electro-motive force existing in Chile. The range of subjects varies from new theories of the physical phenomena, speed of passage of gas molecules, to a great amount of works about electricity and its applications[30].

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[26] Luis L. Zegers, Arturo E. Salazar, "Esperimentos sobre la produkzion de los rrayos de Röntgen por medio de las lamparillas de kadenzia eléctricas", *Actes de la Société Scientifique du Chili*, Santiago, 1896, t. 6, 21.

[27] Martens [35].

[28] Luis L. Zegers, *Tratado Elemental de Física Jeneral*, Santiago, Imprenta Moderna, 1902-3. Volume I (1902, 400 pages) contains Mechanics and instruments of measurement, Gravity, Hydrostatics, Static of Gases, molecular phenomena, and Accoustics. Complementary it has an annex about Dimensions of mechanical geometric and physical quantities (new units from the Congress of 1900 in Paris). Volume II (1902, 313 pages) incluyes Geometrical Optics, the Spectrum (spectral analysis), Double Refraction – Polarization – Rotating Polarization, Notions of Physical Optics and Applications of Optics. Volume III, published in 1903 (390 pages) has the articles: Heat, Notions about mechanical theory of heat, Some industrial and economic applications of heat and Notions of Meteorology.

[29] Gustavo Lira, *Física general*, Santiago, Editorial Galcon, 1942. (Note: mimeographed copy Universidad de Chile, Escuela de Ingeniería). The text has three parts: First part: Mechanics (628 pages) that includes Mechanics, Physics of Solids, Physics of Liquids, Molecular physics of gases. Second part: Heat (420 pages) includes **Thermology** and Thermodynamics. The third part; Electricity (465 pages) includes Electrostatics, Magnetism, Electric current and Electromagnetism.

[30] Woks of the *Cuarto Congreso Científico (1o Panamericano)*, Volume V, Ciencias Físicas, Santiago de Chile, December 25 1908 to January 5 1909, Editor José Ducci, Santiago de Chile, Imprenta, Litografía y Encuadernación Barcelona, 1910.

4.1 Border issues

At the end of the 1920s and beginning of the 1930s, there was a great concern in Chile for the development of science. The first dawning of scientific creation and investigation began as an independent activity. In 1928 a bold initiative is proposed in the Universidad de Chile that finally didn't prosper: "The Faculty of Sciences that has just been founded, separating it from the professional activities the University had to dedicate itself to with preference as it is in a new country, is an effort to give our institution that noble character of the cultivation of science for science"[31]. The Universidad Católica experiments in 1928 with a program of scientific courses that lead to the academic degree of Graduate in Physical and Mathematical Sciences, which caused concern because "a Faculty only dedicated to the disinterested cultivation of science would remain without students". In fact, in time the professional character took priority and the degree of graduate moved to a secondary place[32]. In that same sense, in 1930 the *Chilean Institute of Sciences* was created, "destined to favor and coordinate the investigation of pure scientific studies, that preserves and elevates culture, with no professional aim"[33].

Two years before, in 1928, the Universidad de Chile was visited by the distinguished French physicist Paul Langevin, who gave conferences about his specialty, discussed the recent formulation of "quantum physics"[34] and was granted a honorary membership of the Faculty of Physical and Mathematical Sciences. In that period there were also a series of conferences about the then red-hot topics of physics - the structure of matter and the theory of relativity - aimed at spreading the new physical phenomena among a large public[35]. This scientific awakening occurred in all levels. At the beginning of the 1930s Ziegler´s disciples brought the teaching of this discipline to all corners of the country, and most of the teaching institutions had a well equipped physics laboratory. Another proof of this interest is the *Revista de Matemáticas y Física Elementales (Magazine of Mathematics and Elemental Physics)*, that circulated in Chile in 1930-31[36]. In issues 7 and 8 of 1931, there is a translation of a discussion that took place in the French Society of Philosophy, between Einstein, De Broglie, Borel, Langevin and others about "Determinism and Causality in Contemporary Physics". In 1929 the government reinforced this scientific interest, on one hand with scholarships to perfect studies abroad, on the other with the hiring of a new wave of German professors to teach science at the Universidad de Chile. Among them was Karl Grandjot for mathematics and physics, who obtained his PhD in Göttingen in 1922, where he studied mathematics with Landau, Courant and Hilbert, and experimental and theoretical physics with Peter

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[31] Conferences on University Extension given in the Aula Magna of the Universidad de Chile during the second semester of 1928, Imp. Universitaria, Santiago de Chile, 1929.

[32] Ricardo Krebs, M. Angélica Muñoz and Patricio Valdivieso, *Historia de la Pontificia Universidad Católica de Chile*, Santiago, Ediciones Universidad Católica de Chile, 1993, 297-298.

[33] *Boletín de la Universidad de Chile*, Santiago, 1929, 1114.

[34] Conferences on University Extension given in the Aula Magna of the Universidad de Chile in the second semester of 1928, Santiago de Chile, Imp. Universitaria, 1929.

[35] Ramón Salas Edwards, physics professor of the P. Universidad Católica gave conferences on relativity, published in Ramón Salas Edwards, *Teoría de la Relatividad: Conferencias de Divulgación*, Santiago de Chile, Imprenta Balcells, 1930. About the structure of matter, we have documentation of the conferences of Pablo Krassa, professor of Chemistry-Physics at the School of Engineering of the Universidad de Chile, in 1926, 1932 and 1934, and published as a brochure: Pablo Krassa. Las ideas modernas sobre la materia y la energía, Santiago, Prensas de la Universidad de Chile, 1936, and those of Jacques Barcelin, "Las teorías modernas de la Estructura de la materia", Anales de la Universidad de Chile, Santiago, 1926.

[36] This magazine was published every two months by a group of teachers related to the Pedagogical Institute. Among them were Domingo Almendras, Francisco Canales, Esteban Doña, Enrique Froemel, Jenaro Moreno, Manuel Pérez R., Sansón Radical, Federico Rutlant and Carlos Videla. It had a teacing character, with articles of dissemination, problems and contests.

Debye and Max Born. He had a fast rising career as an investigator in Göttingen, where he graduated in 1926 as *Privatdozent*. When he arrived in Chile, he concentrated on teaching[37].

The spirit of this flourishing is to be seen in the organic statute of the Universidad de Chile of 1931, which formally includes scientific investigation through the institutes of investigation. This boost was temporarily diminished because of the great crisis at the beginning of the 1930s that affected Chile with special force, and later because of the Second World War, that isolated the country from the European scientific and cultural centers. For physics in particular, this situation took a few decades to clear up.

4.2 The first investigation groups

At the end of the 1940s the rhythm is reestablished.

In 1946, Grandjot created the course of theoretical physics in the Pedagogical Institute, which mainly included thermodynamics, theory of waves, quantum mechanics and relativity. As a guiding text he recommended *Introducción a la Física Teórica (Introduction to Theoretical Physics)* by J. Slater and N. Frank, which comprises a large part of those subjects. At the end of the 1940s, the Dean of the Faculty of Philosophy and Education, Juan Gómez Millas promoted the installation of groups of scientific investigation in physics[38]. In 1950 degrees are created at the Pedagogical Institute on the basis of the title of State teacher in Mathematics and Physics. That same year, in the Faculty of Philosophy and Education a group on Nuclear Physics and Cosmic Radiation is formed and another one on Crystallography and Molecular Physics, where teachers who had gone abroad to perfect their knowledge would play an important role[39]. These groups are one of the sources of the first international publications on physics in Chile[40].

Another center of activities was the Faculty of Physical and Mathematical Sciences of the Universidad de Chile. Already in 1945, days after the first atom bomb was thrown, there was a public debate about the disintegration of matter in the School of Engineering of the Universidad de Chile. It was probably the first academic discussion in Chile about nuclear energies and its reaches[41]. In 1947 an *Institute of Physics* is created, established as "a foretaste of a Faculty of Sciences"[42], which, however, would only take off in the 1950s.

At the beginning of 1950 germination began. A study and census of the investigation in the Universidad de Chile reports: "The census of the scientific investigations of the Universidad de Chile shows that there are only 6 investigation centers dedicated to Physics[43], from a total of 43; that is to say 14%. As for the number of physical scientists, they are 31 out of 287, that is to say,

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[37] C. Gutiérrez, F. Gutiérrez, "Carlos Grandjot: tres décadas de matemáticas en Chile", *Boletín de la Asociación Matemática Venezolana*, Caracas, Vol. XI, No 1 (2004), 55-84.

[38] Luis Oyarzún Ed., *Juan Gómez Millas (1900-1987), el legado de un humanista,* Santiago, CPU, 1988. See particularly the section "El valor de las Ciencias", 71-98.

[39] The group of Nuclear Physics and Cosmic Radiation was in charge of Gabriel Labial and the group on Crystallography and Molecular Physics was in charge of Nahum Joel.

[40] In 1953 the two first Chilean publications with a international diffusion on Experimental Physics appeared, one in *Il Nuovo Cimento* 10 (1953) 161, and the other in *Acta Crystallographica 6* (1953) 465. Data in Eugenio Vogel, "Aspectos Históricos del Surgimiento y Desarrollo de la Física en Chile Durante el Siglo XX", Inaugural Conference of the XII Chilean Simposium on Physics. In leaflet SOCHIFI, January 2002.

[41] One of the papers, Transmutación y Desintegración de la Materia: la Bomba Atómica, by Prof. R. Mebus was published as a brochure.

[42] Domingo Santa Cruz, in *Estudios en Honor de Juvenal Hernández,* Corporación Cultural Juvenal Hernández, 2000, 80.

[43] This probably refers to the professorship of Medical Physics of the School of Medicine, that investigated the biological effects of ultrasound, the Physics Laboratory of the School of Engineering, dedicated to microwaves, the Center of Investigations in Glaciology and Geophysics, the Center of Cosmic Radiation and Nuclear Physics, and the Laboratory on Crystallography and Nuclear Physics, both from the Faculty of Philosophy and Education, and the Physics Laboratory of the Faculty of Chemistry.

11%. From the scientists exclusively dedicated to investigation, the numbers of physicists is 8, that is to say, 8%. [..] Furthermore, 3 of these centers were created so recently that one could say that investigation in physical sciences is just beginning in this University"[44].

The next big boost is the creation, in 1954, of the Laboratory of Nuclear Physics in the Faculty of Physical and Mathematical Sciences of the Universidad de Chile. "The rector of the Universidad de Chile, don Juan Gómez Millas, commissioned us in August 1954 to establish a laboratory for nuclear physics. This implied having a group of scientists capable of doing original investigations. We started by studying the fundamental bases of this project", those commissioned wrote[45]. To this end, some graduates from the School of Engineering started to specialize themselves, the Dutch physician Dr. J. H. Spaa was hired and a *Cockroft- Walton* accelerator for ionized particles was bought. The initial group directed by Arturo Arias was integrated by physicists graduated from the Pedagogical Institute that worked on cosmic radiation, as well as by some chemists and biologists[46]. The laboratory pursued experimental and technical activities, and gave courses, seminaries and conferences. The courses were Rational Mechanics, Quantum Mechanics, Nuclear Physics and Reactor Theory. This laboratory was the nucleus of the Institute of Physics and Mathematics founded in 1959. In 1961 the Institute was formed by 38 scientists who were exclusively dedicated to this work, and by 17 technicians. Besides, 12 members of the Institute were doing research and specialized studies in universities in Europe and the United States. The Institute had different sections, among them Nuclear Physics, Crystallography, Thermo ionic conversion of solar energy into electricity, Theoretical Physics and Mathematical Groups, Biophysics, Electronics and tools workshops, libraries and a School of Physics and Mathematics[47]. The investigations by its members were published in "specialized magazines of worldwide circulation"[48].

4.3 A new stage

While until 1960 the development of physics was mainly centered in the Universidad de Chile, it is important to point out that there were also other experiences. The Universidad de Concepción, founded in 1922, soon had the infrastructure for the development of physics. A promoter of this discipline was the Italian physicist Leopoldo Muzzioli, who arrived in Concepción in 1936, and created a group of physicists that became the basis for the forming in 1959 of the

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[44] Nahum Joel, "La Investigación Científica en la Universidad de Chile", *Anales de la Universidad de Chile*, Year CXII, 3o and 4o. trimester, 1954, Nos 95-96, 287-310.

[45] Preliminary report of the Laboratory of Nuclear Physics, Prologue, Arturo Arias and J. H. Spaa.

[46] "Experiencias y Perspectivas del Instituto de Física y Matemáticas", *Boletín de la Universidad de Chile*, No 23, August 1961. There are additional testimonials about the origins of this laboratory in: Igor Saavedra, "El desarrollo científico universitario", pp. 87-95, and Eduardo Schalscha, "El rector", 203-204, both articles in Oyarzún [37].

[47] Until the date of the report (1961), the institute was directed by Carlos Martinoya; the section of Nuclear Physics was directed by J. J. van Loef until 1960, then by Lincoyán González, Jacobo Rapaport and Alex Trier; Crystallography, with three fields: one directed by Nahum Joel and Isabel Garaycochea; another by Enrique Grünbaum and the third by Luis Catalán; Theoretical Physics was directed by Igor Saavedra; Mathematics by Kurt Legrady and Arno Zaddach; Biophysics was directed by George Hodgson; Electronics was directed by Mallén Gajardo; the workshops were directed by Egbert Hesse; and the school itself was under direction of Darío Moreno. Data taken from the Bulletin of the Universidad de Chile.

[48] The report of 1961 published in the previously quoted Bulletin of the Universidad de Chile, states that there have been articles in: Acta Crystallographica, American Journal of Physics, Biochimica et Biophisica Acta, Blood, Bulletin de la Societé Francaise de Cristallographie, Comptes Rendus de l'Academie des Sciences, Journal de Chimie Physique, Mineralogical Magazine, Nature, Nuclear Instruments & Methods, Nuclear Physics, Nuovo Cimento, Philosophical Magazine, Physical Review, Proceedings of the Cambridge Philosophical Society, Proceedings of the Physical Society, Proceedings of the Royal Society, Proceedings of the Society of Experimental Biology and Medicine.

Instituto Central de Física Experimental y Teórica (Central Institute of Experimental and Theoretical Physics). The Universidad Técnica Federico Santa María, which opened its doors in 1928, had a strong boost with the arrival, after the Second World War, of PhD Arnold Keller, an outstanding experimental physicist who had worked in German military projects. He published on a national level in Chile (see *Scientia* magazine) and dedicated himself mainly to teaching. Meanwhile, in the Santiago campus of the Universidad Técnica del Estado (nowadays USACH), a Physics Institute is organized in 1955, dependent on the School of Industrial Engineers.

The Pontificia Universidad Católica de Chile was founded in 1888. As we have mentioned, the first initiative in the area of Physics itself is in 1928, when engineering students were offered the possibility to obtain the degree of Graduate in Physical and Mathematical Sciences.

In 1947 DICTUC, Departamento de Investigaciones Científicas y Tecnológicas (Department of Scientific and Technological Investigations) was founded, where later on a Physics laboratory was organized, which formed the basis of the School of Physics inaugurated in 1963.

In the 1960s Physics became professionalized in Chile. Halfway through the 20th century, physics ceased to be an activity of isolated individuals, who many times worked in different directions and during partial time, and became a professional activity, with a community that comes together, shares their works and defines and develops the discipline.
Emblematically, the *Sociedad Chilena de Física* was founded at the beginning of the 1960s (May 28th 1960)[49], though only years later, on December 9th 1965, the decree 26.310 that legalizes it, appeared in the *Diario Oficial*.

Halfway through the 1960s Science Faculties were created in universities, and with this the creation of Physics departments began. Around that time there was a consolidation of the Investigation Institutes; in 1964 the Comisión Chilena de Energía Nuclear (Chilean Commission for Nuclear Energy) was founded, a paradigm of the application and use of physics; and in 1967 the Comisión Nacional de Investigación Científica y Tecnológica CONICYT (National Comission of Scientific and Technological Investigation) was founded. In this way, scientific investigation in experimental and theoretical physics becomes established. Proof of this is the number of physicists living in the country and their international publications[50].

As from the 1960s a new stage begins for physics and for all sciences in Chile. Fortunately this stage is more documented than those before (see for example the references [15, 35, 39, 40, 28] in the bibliography) and deserves a study of its own.

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[49] The date of foundation appears in the *Directorio de Instituciones Científicas en Chile*, Ed. Centro de Cooperación científica de la UNESCO para América Latina, en colaboración con la OEA, Montevideo, 1968. Eugenio Vogel, in [41], recalls its founders were the physicians J.J. van Loef, N. Joel, J. Rapaport, L. Muzzioli and A. Keller.

[50] *Directorio de Científicos de Chile*, Ed. Centro de Cooperación científica de la UNESCO para América Latina, en colaboración con la OEA, Montevideo, 1966.

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