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WORK DEDICATED TO THE INTERNATIONAL YEAR OF PHYSICS - 2005

STATISTICAL STUDY OF THE PHYSICS DEVELOPMENT IN THE LAST CENTURY

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Anul 2005 a fost atât primul An internaţional al Fizicii, cât şi anul reformei învăţământului universitar din România. Pornind de la studiul evoluţiei Fizicii în ultimul secol, această lucrare şi-a propus să studieze şi implicaţiile privind predarea Fizicii în Universităţile tehnice. În diferite forme: a) reducerea orelor de predare a Fizicii, b) coborârea predării Fizicii în primele semestre universitare, c) reducerea semnificativă a ponderii studenţilor din ciclul Bachelor care aleg Fizica ca disciplină de studiu, etc., predarea Fizicii s-a redus sensibil în multe facultăţi tehnice, în ultimii 30 ani, în contradicţie cu rezultatele remarcabile obţinute în Fizică în acest timp. Lucrarea de faţă analizează cauzele acestei involuţii, în principal: a) cele legate de exigenţele de eficienţă tehnică şi financiară maximă a învăţământului tehnic universitar de bază (ciclul Bachelor), inclusiv riscurile pe termen lung ale reducerii predării Fizicii, şi: b) cauzele specifice Fizicii şi disciplinei Fizica din învăţământul tehnic universitar.

The year 2005 was both the first International Year of Physics, and the year of the academic education reform in Romania. Starting from the study of the Physics evolution, this work aimed to study the implications concerning the Physics teaching in the technical Universities. In different manners: a) the decrease of Physics teaching hours, b) the descent of Physics teaching in the first academic semesters, c) the significant reduction of the weight of Bachelor students who choose Physics as a study discipline, etc, the Physics teaching has been reduced considerably in many technical faculties in the last 30 years, in contradiction with some outstanding results obtained in the same period by the scientific research in Physics. This work analyses the main causes of this involution, mainly: a) the causes related by the requirements of maximum technical and financial efficiency, the long-term risks of the Physics teaching decreasing, inclusively, b) the causes specific to Physics and to the Physics teaching in the technical Universities.

Keywords: Physics evolution, main results obtained by the works awarded with Physics Nobel prizes, technical and financial efficiency of Bachelor cycle in technical faculties, risks of the Physics teaching decrease, possibilities of Physics teaching improvement in technical faculties.

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Introduction

As it is well-known, the United Nations (UN) General Assembly has adopted the resolution A/58/L.62, declaring 2005 as the International Year of Physics, and invited the United Nations Educational, Scientific and Cultural Organization (UNESCO) to organize activities celebrating this Year (see also the web page: http://www.un.org/Depts/dhl/resguide/r58.htm). In frame of the UN press release GA/10243 it was shown: "In 1905, Albert Einstein had published several scientific articles that profoundly influenced understanding of the Universe. The aim of the International Year went beyond the mere celebration of one of the greatest minds in Physics in the twentieth century. The Year would provide an opportunity for the largest possible audiences to acknowledge the progress and importance of the great field of science".

As it is well-known, the field of Physics results and predictions has now absolutely amazing dimensions: magnitudes orders of some essential Physics events from about 10^{-43} s (corresponding to the unification duration of the gravitational interaction with the other 3 (quantified) ones, after the initial Big Bang explosion) [1] up to 10^{41} s (the proton disintegration time) [2]! Due to the outstanding predictions and technical achievements of Physics applications from the interval 1935-1965, especially, corresponding to the: a) nuclear weapons, b) building of the first nuclear reactors intended to the obtainment of additional electrical power, c) beginning of transistors use, d) prediction and manufacture of lasers, etc. the Physics teaching in the technical Universities has known a significant increase in this period. After 1975, mainly, in different forms, the Physics teaching in the technical Universities begun to reduce, gradually and considerably.

That is why this work will examine in detail the Physics evolution in the last century, trying to point out the main reasons (objective or subjective) of the decrease of Physics teaching in technical Universities, in the last 30 years.

1. Study of the Physics evolution in the last century

Taking into account the remarkable importance of the Nature sciences studies, the corresponding number of published works is huge: approx. 654,000 scientific works published in international journals in 2000, and even more published scientific works in the domestic reviews (e.g. only in China there were published approx. 181,000 scientific works in the Chinese scientific reviews) and – correspondingly – the number of yearly published abstracts of these scientific works is also huge: approx. 180,000 Physics abstracts/year, approx. 105,000 Electrical & Electronics abstracts/year, approx. 100,000 Computer & Control abstracts/year, etc.

For this reason, the number of recognised scientific fields is also extremely large; e.g. according to the *Physics Abstracts* classification a (sub)domain of Physics is given by a combination of 4 digits and a letter, therefore it seems to exist approximately 200,000 sub-domains of Physics! Between the Physics and the technical sciences there is a strong connection, and for this reason the *Physics Abstracts* review became a part of the INSPEC database, co-ordinated by the IEE (Institute of Electrical Engineers) organisation. According to the INSPEC classification [3] there are 61 main fields of Physics, 37 main fields of the Electrical and Electronic Engineering, 23 main fields of Computer and Control sciences, 9 main fields of the Manufacturing and Production engineering, and other 5 main fields of the Information Technology (IT).

Due to the huge number of the scientific and technical domains (even of the main domains) and of the published scientific and/or technical works, the teaching of the basic elements of Physics requires the selection of the most important results, namely of those elements that were generally recognised for their particular importance. Though we cannot affirm that any scientific results awarded by Nobel prizes is more important than any other results that didn't obtain a Nobel prize, we consider that all most important scientific (and even technical) results were recognised by Nobel prizes. That is why, we will use the brief analysis of the results recognised by Nobel prizes in order to point out the evolution of the Physics development in the last century. We will mention the previous work referring to the statistical study of the Physics Nobel prizes (but only up to 1990) [4], as well as our main sources used for a complete statistical study for the whole interval 1901-2005 [5].

The results obtained by means or the accomplished analysis were synthesised by Tables 1-9, that indicate: the main fields of the research works awarded by Physics Nobel prizes (Table 1), the evolution of these main fields along the decades of the interval 1901-2005 (Table 2), the evolution on decades and countries of the awarded Physics Nobel prizes (Table 3), the distribution on countries of the awarded Physics Nobel prizes (Table 4), the countries classification on the ratio of the total number of scientific activities years (see Table 4) of some Physics Nobel prize laureates in frame of the national institutions and the corresponding country population (Table 5), the classification of Universities and scientific research institutions depending on the number of graduate titles (Bachelor, Master and/or Doctors) and the number of activity years accomplished by the Physics Nobel laureates in frame of these institutions (Table 6), main results obtained by the Physics Nobel laureates with Engineering studies and/or studies in Technical Universities (Table 7), the families of Physics (or Chemistry) Nobel prize laureates of other outstanding physicists (Table 8), and the Physics Nobel prize laureates with noble origin and their highest academic studies (Table 9).

Table 2 shows that the main topics corresponding to the awarded Physics Nobel prizes (PNP) can be classified as it follows:

a) *topics recognised as important for technical applications by practically all engineers* [6]: Thermodynamics (2 awarded PNP) and Electromagnetism & electromagnetic waves (5 awarded PNP) = totally 7 PNP (all awarded up to 1919), representing approximately 6.31% from the 111 main Physics topics corresponding to the awarded Physics Nobel prizes,

b) *important Physics topics for the understanding of the work of practically all modern technical devices:* Optics (11 awarded PNP), Quantum Physics (7 PNP), Condensed Matter Physics (20 PNP) = totally 38 PNP (awarded between 1902 and 2005), representing about 34.23% from the 111 main Physics topics corresponding to awarded PNP,

c) *important Physics topics for the understanding of the work of the modern devices specific to certain technical specialties:* Spectroscopy (9 PNP), Atomic and Molecular Physics (11 PNP), Nuclear Physics (11 PNP), Plasma Physics (2 PNP) = totally 33 PNP (awarded between 1902 and 2001), representing about 29.73% of all main Physics topics awarded with PNP,

d) *important Physics topics for future, but that are not presently used in technical applications:* Elementary Particles & Fundamental Interactions (27 PNP), Astrophysics and Cosmology (6 PNP) = totally 33 PNP, representing also 29.73% of all main PNP topics.

Diagram 1 presents a synthesis of these awarded PNP, corresponding to the main Physics fields and to the main matter organising levels.

The examination of Table 1 and of Diagram 1 allows to point out also:

(i) the huge set of matter organising levels covered by the Physics studies from the last century,

(ii) the "return" in the last 30 years of the preoccupations for studies in the fields of Optics, Microscopy and Diffractometry, of Spectroscopy, and of Atomic and Molecular Physics, respectively, by means of new experimental methods (neutron diffraction methods, laser, electron and neutron spectroscopy, Bose-Einstein condensation in dilute gases, etc).

(iii)the "polarisation" of the most important Physics researches, approximately 30% from the awarded Physics Nobel prizes (and a percentage even higher in the last years) corresponding to topics located at the extremities of the matter organising levels: the elementary particles and fundamental interactions (27 PNP) and the astrophysics and cosmology (another 6 PNP).

2. Evolution of the Physics teaching in the technical Universities in the last 30 years

In different countries and different technical faculties there were 3 types of Physics teaching decreasing:

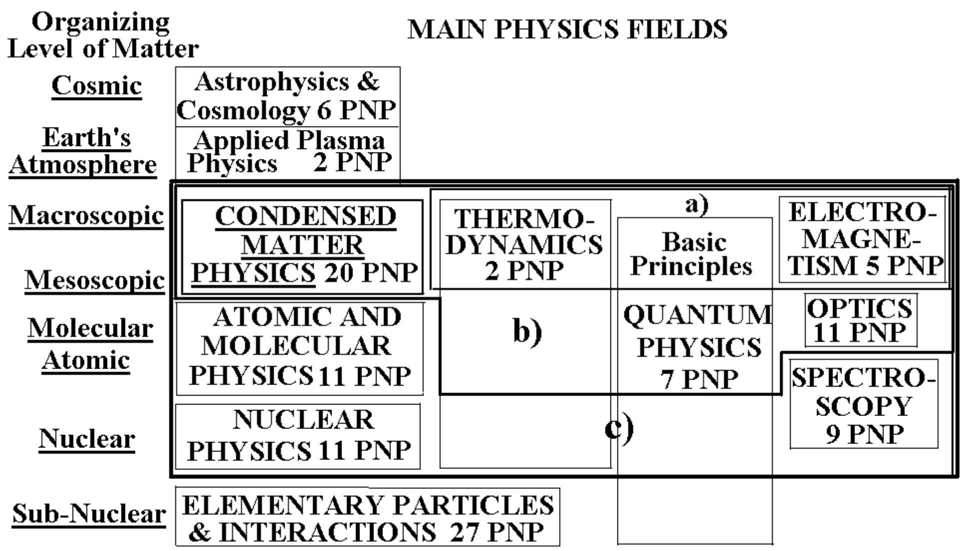

Diagram 1. Main Physics fields vs. corresponding matter organising levels

a) by elimination of some chapters, usually of the chapters of Modern Physics,

b) by descending the Physics teaching semesters, that obliged the Physics professors to present to students some basic notions of Mathematics, Mechanics, etc.

c) by reduction of the number of students that choose the Physics disciplines for their academic program [7].

In order to evaluate the magnitude orders of these changes we will choose some very simple (rather non-accurate) models, attaching: a) to each chapter the weight corresponding to its ordering number (from Table 2) times the relative weight of the respective chapter, b) to each Physics teaching semester its position in the education plan (i.e.: the academic semester II = 2p, the semester III = 3 p, etc).

As an example of type a) of Physics teaching reductions, we will choose the faculty of Control Systems and Computers of University “Politehnica” from Bucharest[1] (UPB). Here, the taught Physics chapters and their relative weights were: **1976 –** Thermodynamics (1), Electromagnetism & Electromagnetic Waves (2), Optics & Microscopy (3), Spectroscopy (4 × 0.25 = 1), Atomic and Molecular Physics (5), Quantum Physics (6), Condensed Matter Physics (7), Nuclear Physics (8 × 0.5 = 4), Elementary Particles and Fundamental Interactions

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[1] The situation is practically the same at all technical faculties of the electrical profile from Romania.

(9 × 0.25 = 2.25), Plasma Physics (10 × 0.25 = 2.5), totally **33.75 p**, **1991** – Mechanics (1), Thermodynamics (1), Electromagnetism & Electromagnetic Waves (2 × 0.5 = 1), Optics & Microscopy (3 × 0.25 = 0.75), Spectroscopy (4 × 0.15 = 0.6), Atomic and Molecular Physics (5), Quantum Physics (6), Condensed Matter Physics (7 × 0.75 = 5.25): totally **20.6 p, 2006** (according to requirements of work [6]): Mechanics (2), Thermodynamics (1), Electromagnetism (2 × 0.5 = 1), Basic Principles of Quantum Physics (6 × 0.25 = 1.5), **totally 5.5 p.**

As an example of type b) of Physics reductions, we will choose the faculty of Electronics from UPB. Here, the number of Physics teaching semesters remained the same (3 semesters), but their position descended from the semesters IV-VI (that allowed to Physics professors do not explain any element of Mathematics, Mechanics, Electromagnetism, because the students promoted the respective disciplines before the Physics course beginning), in the years 1970' to the semesters I-III, presently. Using the above (very much) simplified model, it results that the weight of the Physics teaching semesters decreased from the total sum of **15 p** (in years 1970') at only **6 p** (now), that is less than for the above indicated faculties, but … representing also a rather drastic reduction!

The last case c), corresponds to many occidental technical faculties, where the Physics curricula remained the same, but here the main difficulty refers to the decreasing number of students choosing the scientific disciplines (Physics, mainly) for their academic program.

Approaching now in detail the problem of Physics teaching in the technical Universities, we have underline from beginning that this discipline has some specific features.

3. Physics – as a humankind "engine"

It is well-known the outstanding role of Physics in the development of all natural sciences, of the technical sciences, inclusively.

As it concerns its own structure, the Physics operation is somewhat similar to an engine with 2 pistons. The experimental research leads to the discovery of new phenomena and empiric laws, whose interpretation imposes some theoretical hypotheses, named *theoretical laws or principles*. Because these theoretical laws were obtained by **incomplete** induction (they were rather "guessed"), the ensemble of Physics principles is not equivalent to the corresponding experimental findings that generated these principles.

For this reason, the thorough study of the Physics principles' consequences (the field of Theoretical Physics) leads frequently to predictions of some processes that were not at all assumed and studied previously (this is the case of the Special and General Relativity theory, of the nuclear energy, lasers, etc). In such a manner, Theoretical Physics has also an essential role for the general development of Physics, as it can be found also from the examination of Table 1.

That is why the attempts to eliminate one of the 2 above indicated types of Physics knowledge [as it was the more than one century old attempt[2] of Ernst Mach to eliminate the outstanding Statistical Physics theory (and its underlying atomism ideas) of Ludwig Boltzmann] can have only bad consequences for the general Physics development, and for the Physics education of specialists.

We have to underline also: a) the strong connection of the main 2 Physics methods, pointed out also by the strong preoccupation of some Theoretical Physics institutions [as the Abdus Salam International Center for Theoretical Physics (ICTP) from Trieste, Italy] for direct applications in many experimental fields, e.g.: Physics of Condensed Matter, Physics and Energy, Physics and Technology, Earth and Environmental Sciences, Space Physics, Physics of the Living State, Topics at the Interface with Chemistry, Engineering, Biology, Instrumentation for Nuclear and Sub-nuclear physics [9], b) the importance of both main Physics methods in engineering, the first one for the new qualitative knowledge about the physical phenomena and their **technical applications, and the second** one for its possibilities to contribute to the design of different technical devices, inclusively.

4. Technical and financial causes of the Physics teaching decreasing in the technical Universities in the last 30 years

It is well-known that each human organisation tends to improve its (technical and financial) efficiency. Due to the considerable inappetence of many Bachelor students for theoretical studies (Mathematics, Physics, mainly), a possible orientation is to restrict these theoretical elements to a minimum quantity, that will allow also to use the remained time for the teaching of some additional (qualitative) technical details. Taking though in account the above indicated strong connection of the Physics experimental and theoretical notions, this kind of efficiency is real, but … it is one of short term!

As it concerns the opinions of the technical Universities leaderships relative to the usefulness of the Physics elements teaching in the undergraduate

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[2] Taking into account the importance of such attempts, we will present here a short excerpt of the paper [8] of the Physics Nobel prize laureate (2004) Franck Wilczek: "Mach's austere **empiricism** is a disinfectant that, taken too far, can induce sterility. Mach himself never accepted special relativity. He also denounced **atomism** and harassed his great contemporary Ludwig Boltzmann over it. In private correspondence, Einstein wrote that Mach's approach to science "cannot give birth to anything living, it can only exterminate vermin". Yet in this sharp statement, I believe Einstein meant to be judicious. Exterminating vermin is a necessary and sometimes challenging task, even it is not so transcendent as giving birth. In the world of ideas, as opposed to the world of events, we can choose what to retain".

cycle, it seems that there are now 3 main opinions, corresponding to the short-, medium- and long-term efficiency:

(i) *the restriction of the taught Physics elements in the undergraduate cycle only to the elements belonging to the above item a), with very few additional elements concerning the principles of the Quantum Physics:* opinion of some European organisations [6][3], etc. (short-term efficiency),

(ii) *the necessity to ensure the teaching in the undergraduate cycle of the Physics knowledge corresponding to the topics of the above a) and b) items, and – depending on the specific technical specialty – also of some notions belonging to the above item c)*: technical academic education feature in France, Italy, Israel, etc. (medium-term efficiency),

(iii) *the necessity to ensure unique Physics textbooks for scientists and engineers (involving the topics on Elementary particles & Fundamental interactions, Astrophysics and Cosmology)*: specific mainly to the American and UK Universities [10]-[12], etc. (long-term efficiency).

5. Internal causes from Physics

The detailed analysis of the Physics evolution from the last century points out that: a) Physics had absolutely outstanding results in the description of the simple and complicated systems[4], for the explanation of some phenomena, the prediction of new phenomena, and the design of some devices (as the fission nuclear reactions, semiconductors, theory of classical superconductivity, design of lasers, etc); b) despite the remarkable efforts and even results obtained in the description of some complex systems[5], we have to recognise that Physics does not have yet sufficiently efficient procedures for the description of the complex

[3] The work [6] does not require for the Bachelor students of the technical faculties any notion of Theoretical Physics: nor Relativity theory, or Analytical mechanics, Statistical physics, Maxwell's equations of electromagnetism, the operation notions of Quantum Physics, etc.

[4] If the description of a physical system does not require any similitude criterion, it is called *a simple system*; conversely, if this description needs the use of 1 similitude criterion, the system is named a *complicated physical system*.

[5] It seems that the notion *Complexity* was introduced first by the electrical engineers [13]. P. W. Anderson (Physics Nobel prize laureate in 1977) is considered as founder of Complexity theory in Physics [14]. Another contributions extremely important to the Complexity theory in physical sciences were achieved by Ilya Prigogine (Nobel prize laureate in Chemistry, 1977) [15]. A detailed explanation of the physical properties of complex systems by means of successive averages on the fluctuations at different organizing levels (starting from the lowest levels up to the highest active ones) was offered by Kenneth G. Wilson (Physics Nobel prize laureate in 1982). According to K.G. Wilson - *the complex physical systems* are those inside whom are active concomitantly physical processes at different matter organizing levels. Additional essential contributions to the Complexity theory in Physics were presented by P. G. de Gennes (Physics Nobel prize laureate in 1991) in frame of his theory of the "soft matter" (liquid crystals, etc).

systems [for this reason, Physics failed to: (i) predict the superconductivity at high temperatures, and even the theoretical explanation of this phenomenon, (ii) achieve the fission nuclear reactors, and even to design some very important devices (for technical goals) as: (iii) the integrated circuits, that were obtained outside Physics, even their main author – prof. J. S. Kilby was awarded by the Physics Nobel prize in 2000, etc]. Generally, we can find that – despite the huge effort done in frame of the Condensed Matter Physics field – Physics has real difficulties to describe some dependencies of physical parameters (as the size-effects[6], the temperature and frequency dependencies, etc) that are very important for many engineers.

Additionally, the Physics teaching in the Bachelor cycle of technical Universities seems to be (with few exceptions) too "conservative", i.e. no elements about: (i) the physical similitude[7], (ii) fractals, (iii) chaos (excepting e.g. [16]), (iv) solitons, and generally about the main features of complex systems (power laws[8], limit-laws, equations of accommodation and dis-accommodation processes, etc). In such conditions, some scientific disciplines (neighbour to Physics, mainly Mathematics) have taken some of Physics attributions. The unique solution: the urgent introduction in the Physics courses from the technical faculties, at least of a Chapter intended to the description of the physical complex systems, as well as a more accentuated concern of Physics professors from the technical Universities for scientific research topics in this field!

Taking into account that Physics is itself a rather complex and difficult scientific discipline, it is necessary also to pay attention more to the recent studies (e.g. [18]) that stress out the necessity to: a) minimise the cognitive load by limiting the amount of material presented (see also [19]), b) have a clear organisational structure of the presentation, c) link new material to ideas that the audience knows, d) avoid unfamiliar technical terminology, e) point out frequently the applications of the taught notions in the work of usual systems, f) use new educational technology (clickers, peer instruction technique [20], etc).

Conclusions

Taking into account: a) the Henri Poincaré's definition [21] of the scientific method "*The scientist must order. Science is made with facts as a house with*

[6] For this reason, some outstanding researchers from Engineering fields, were obliged to use some auxiliary methods, as those offered by the Fractal theory.

[7] The use of similitude criteria in the engineering sciences, for the study of some physical phenomena (fluids dynamics, thermal exchanges, etc) *in complex systems* is already rather old!

[8] We mention that one of authors (D.I.) – studying some technical materials - met some Complexity features (power laws) even in frame of his first scientific work [17].

stones; but an accumulation of facts is no more a science than a heap of stones is a house!", b) the original character of the synthetic tables and interpretations involved by this work, we aimed to ensure a rigorous scientific study of the topics examined by the present work.

The accomplished study pointed out the: a) risks of the Physics teaching reduction in the Bachelor cycle of technical faculties, b) necessity of a considerably more accentuated concern of the Physics professors from the technical Universities for the: (i) scientific research of Complex systems and of their physical description, (ii) introduction (in the Physics courses) of more elements concerning the description of Complex systems, (iii) modern didactic technologies, intended to facilitate the understanding of the basic notions of Physics by the Bachelor cycle students.

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Table 1. Classification of the main fields of the research works awarded by Physics Nobel prizes (between 1901 and 2005) according to their Specific Experimental or Theoretical Main Results (the year of Nobel Prize awarding is indicated finally)

Nr.	PHYSICS FIELD	Experimental Studies					Theoretical Studies	
		New Devices	New Methods	Major Findings of Experim. Studies & Tests	New Phenomena	New Physical Objects or States	Theoretical Models	Deductive Theoretical Studies
1	**Thermodynamics**	Illuminating Automatic Regulators & Gas Accumulators, 1912					Van der Waals model of real gases, 1910	Thermodynamic theory of thermal radiation, 1911
2	**Electromagnetism (Emg) & Electromagnetic Waves (radiation & propagation)**	Wireless telegraphy (Radio), 1909		Michelson-Morley experiments (test of "ether" hypothesis), 1907		X-rays: Röntgen, 1901	Heat Radiation laws: Wien, 1911; Energy Quanta: Planck, 1918	
3	**Optics, Microscopy & Diffractometry**	Emg Optics, 1902; Michelson interferometer, 1907; phase contrast microscope, 1953	Color Photography, 1908; Holography, 1971; Electronic microscope, 1986		Diffraction of: a) X-rays, 1914; b) electrons/crystals 1937; c) neutrons, 1994			Bragg-Bragg law of X-rays diffraction, 1915; Quantum theory of optical coherence, 2005
4	**Spectroscopy**	X-rays Spectroscope, W.H. Bragg, 1915 Laser-based precision spectroscopy, 2005	Spectral methods: X-rays, 1924; hertzian waves, 1966; laser & e^-, 1981; ionic traps, 1989; neutrons, 1994	Characteristic X-rays spectral lines, 1917; Fine structure of H spectrum, 1955	Effects: Zeeman, 1902; Stark, 1919; Raman, 1930			
5	**Atomic and Molecular Physics**	Ammonia (NH_3) maser, Townes, 1964	Procedure of gas densities determination, 1904; atoms cooling by means of laser radiations, 1997	Cathodic radiation study, 1905; Experiments of: Franck-Hertz, 1925; Jean Perrin, 1926	Compton effect, 1927	X-rays (Röntgen, 1901); Bose-Einstein condensation in dilute gases, 2001	Bohr's atomic model, 1922	Theory of photoelectric effect: Einstein, 1921
6	**Theoretical Physics (only Quantum Physics;** relativity & gravitation, only implicitly in 1921, A. Einstein)						Energy Quanta, Planck, 1918; Associated waves: de Broglie, 1924	Relativity & Gravity theories: 1921 Quantum theory: Heisenberg, 1932 Schrödinger, Dirac, 1933; Pauli, 1945; Born, 1954; Quantum electrodynamics, 1965

Table 1 (following)

Nr.	PHYSICS FIELD	Experimental Studies					Theoretical Studies	
		New Devices	**New Methods**	**Major Findings of Experim. Studies & Tests**	**New Phenomena**	**New Physical Objects or States**	**Theoretical Models**	**Deductive Theoretical Studies**
7	**Condensed Matter Physics**	Transistor, 1956; Tunnel Diode: Esaki, 1973 Semiconductor hetero-structures & Integrated circuits, 2000	Neutron Diffraction Methods, 1994	Special Alloys, 1920; High pressure phenomena, 1946; Tunneling in Superconductors: Giaever, 1973	Effects: Mössbauer, 1961; Quantum Hall effect, 1985; Fractionally quantum Hall effect, 1998	Liquid Helium: 1913; Antiferro-magnetism, 1970; Liquid helium superfluidity, 1978; High temperatures superconductivity, 1987	Richardson's model of the thermionic emission, 1928; Models of Liquid Crystals and Polymers, 1991; theory of superconductors and superfluids, 2003	Liquid Helium: 1962; BCS Theory, 1972; Josephson's effect theory, 1973; Magnetic & Disordered Systems, 1977; Critical Phenomena theory: Wilson, 1982
8	**Radioactivity and Nuclear Physics**	Wilson's cloud chamber, 1927; Automated cloud chamber, 1948	NMR, 1944; High accuracy nuclear magnetic measurements, 1952; Coincidence method, 1954	Main radioactive substances properties: P. & M. Curie, 1903	Radioactivity: Becquerel, 1903; Nuclear reactions with slow neutrons:Fermi,1938; Cerenkov effect, 1958	-	Nuclear Shell Structure: Goeppert-Meyer & Jenkins, 1963; Combined Nuclear Structure: Bohr-Mottelson, 1975	Exclusion principle and β decay theory: Pauli, 1945; Atomic nucleus theory and fundamental symmetry principles: Wigner, 1963
9	**Elementary Particles and Fundamental Interactions**	Cyclotrone, 1939; Nuclear plates, Powell, 1950; Bubble chamber, 1960 & 1968; Multiwire proportional chamber, Charpak, 1992	For *e*, *h* measurement, 1923; e^- magnetic momentum, 1943 and 1955; For the study of quarks, 1990	Discovery of electron by means of *the study of electrical conduction in gases*, 1906	Interactions of *p* and nuclei, 1951; Violations of the *P* (1957) and *CP* (1980) symmetry	Discoveries of: *n*,Chadwick 1935; e^+,Anderson 1936 π, Powell, 1950; p^-, Chamberlain 1959; *J/ψ*, Richter-Ting,1976 *W*, *Z*, 1984; ν_μ (1988), $\bar{\nu}_e$, ν_K (1995)	Structure of nucleons, Hofstadter, 1961; Classification and interactions of elementary particles, Gell-Mann, 1969; Weak and electro-magnetic interactions unification, 1979; Quantum structure of electroweak interactions, Hooft-V. 1999	Theoretical prediction of mesons, Yukawa, 1949; Discovery of the asymptotic freedom of the strong interaction, Gross, Politzer, Wilczek, 2004
10	**Plasma Physics**					Ionosphere, Appleton, 1947	Applications of magneto-hydrodynamics theory, Alfvén, 1970	
11	**Astrophysics and Cosmology**	Radio-telescope, 1974		Discovery of cosmic X-rays sources & detection of cosmic neutrinos, 2002		Pulsars, 1974; binary pulsars, 1993 Cosmic back-ground radiation, 1978	Energy production in stars, H.A. Bethe, 1967	Evolution of stars, S. Chandrasekhar, W.L. Fowler, 1983

Table 2. Evolution of the Topics of the Scientific Works awarded with Nobel Prizes on decades (1901-2005)

Nr.	PHYSICS FIELD	20th CENTURY DECADE										2000-2005	Total 1901-2005
		1901-09	1910-19	1920-29	1930-39	1940-49	1950-59	1960-69	1970-79	1980-89	1990-99		
1	**THERMO-DYNAMICS**	-	Real gases 1910: Gas Accumula tors, 1912	-	-	-	-	-	-	-	-	-	**2**
2	**Electromagne-tism &Electro-magnetic Waves (radiation & propagation)**	Xrays.1901: Test of "ether" hypothesis. 1907: Wire-less tele-graphy, 1909	Heat ra-diation laws: Wien, 1911; Ener-gy quanta, Planck, 1918	-	-	-	-	-	-	-	-	-	**5**
3	**Optics, Microscopy & Diffractometry**	Lorentz,'02; Michelson, '07: Lipp-mann,1908	Diffraction X-rays,'14: 3D diffrac-tion law,15	-	Diffraction of elec-trons/ crystals,'37	-	Phase contrast microscope 1953	-	Holo-graphy, 1971	Electronic micro-scope, 1986	Neutron Diffraction Methods, 1994	Optical coherence in quantum theory,'05	**11**
4	**Spectroscopy**	Zeeman effect, 1902	Stark effect, 1919	X-rays spectro-scopy,'24	Raman effect, 1930	-	Fine struc-ture of H-spectra,55	Hertzian spectro-scopy,'66	-	laser & e⁻ spectrosco-py,81;ionic traps,'89	Neutron spectro-scopy,'94	-	**9**
5	**Atomic and Molecular Physics**	X-rays,1901; Procedure of gas densi-ties determi-nation, 1904; Cathodic radiation study, 1905	-	Photoelec-tric effect theory,'21 Atomic model,'22 Experim. Franck-H. '25:Perrin, 26; Comp-ton eff.,27	-	-	-	Quantum electronics: Ammonia (NH_3) maser, Townes, Basov, Prokhorov 1964	-	-	Atoms cooling with laser radiation, S. Chu, C. Cohen-Tanoudji, W.Phillips 1997	Bose-Ein-stein con-densation in dilute gases, E.Cornell-Wketterle C.Wieman 2001	**11**
6	**Theoretical Physics** (only **Quantum Physics;** relativity & gravitation, only implicitly, 1921)	-	Electro-magnetic waves energy quantiza-tion, 1918	1921, **Im-plicit:** Relativity & Gravity theories; Asso-ciated waves: de Broglie, 1924	**Quantum theory:** W.Heisen-berg 1932; Schrö-dinger, Dirac, 1933	**Quantum theory:** W. Pauli, 1945	**Quantum theory:** M. Born, 1954	**Quantum electro-dynamics** S. I. Tomo-naga, J. Schwinger, R. P. Feyn-man, 1965	-	-	-	-	**8**

7	**Condensed Matter Physics**	-	Liquid Helium: H. Kamerlingh-Onnes 1913	Special Alloys: Ch. E. Guillaume, 1920; Richardson model of thermionic emission theory: 1928	-	High pressure phenomena: P.W. Bridgman, 1946	**Transistor** W. B. Shockley-J.Bardeen-W.H. Brattain 1956	Mössbauer Effect, 1961; Liquid Helium theory: L. D. Landau, 1962	Antiferromagnetism, 1970; BCS theory,'72; Josephson effect theory&tunnel diode, '73; Magnetic &Disordered Systems, '77; Liquid He superfluidity,'78	Critical Phenomena theory: K.GWilson 1982; Quantum Hall effect: K.von Klitzing 1985; High temperatures superconductivity, 1987	Models of Liquid Crystals and Polymers: de Gennes,91; Neutron Diffraction Methods, 1994; Fractionally quantum Hall effect, 1998	Semiconductor heterostructures (Z.H. Alferov & H. Kroemer) and **Integrated circuits** (J. S. Kilby), 2000	**19**
8	**Radioactivity and Nuclear Physics**	Radioactivity (Becquerel) & radioactive substances properties (P.&M. Curie), 1903	-	Wilson's cloud chamber, 1927	Nuclear reactions with slow neutrons: E. Fermi, 1938	Nuclear Magnetic Resonance, 1944; Exclusion principle and β decay theory: W. Pauli, 1945 Automated cloud chamber,48	High accuracy nuclear mg. Measurements, Bloch& Purcell,'52; Coincidence method, W.Bothe54 Cerenkov effect,'58	Nuclear Shell Structure (Goeppert-Meyer & Jenkins), & Atomic nucleus theory&fundamental symmetry principles: Wigner,'63	Combined Nuclear Structure: A.N. Bohr - B. J. Mottelson, 1975	-	-	-	**11**
9	**Elementary Particles and Fundamental Interactions**	Discovery of electron by *the study of electrical conduction in gases*, 1906	-	Compton effect, 1927	Discoveries of: n, Chadwick 1935; e^{+}: Anderson 1936; Cyclotrone, 1939	e^{-} magnetic momentum, O. Stern,1943; Theoretical prediction of mesons, Yukawa, 1949	Nuclear plates, Powell, 1950; Interactions p - nuclei, '51; e^{-} mg. momentum '55; Violations of P symmetry, '57; $\bar{p}$, Chamberlain, 1959	Bubble chamber, 1960&'68 Structure of nucleons, Hofstadter, '61; Classif. & interactions of elementary particles, Gell-Mann, '69	Discoveries of: J/ψ, Richter-Ting, 1976; Weak and electromagnetic interactions unification, S.Glashow-A.Salam-S.Weinberg 1979	Violation of the CP symmetry, J.W. Cronin, V.L. Fitch,1980; Discoveries of: W, Z, Rubbia & van der Meer,'84; ν_{μ},'88	Study of quarks, '90; Multiwire proportional chamber, 1992; Discoveries of: $\bar{\nu}_{e}, \nu_{K}$ '95; Quantum struct. electroweak interactions;'99	Discovery of the asymptotic freedom of the strong interaction D.J.Gross, H.Politzer F.Wilczek 2004	**27**
10	**Plasma Physics**	-	-	-	-	Ionosphere, Appleton, 1947	-	-	Appl. magnetohydrodynamic,70	-	-	-	**2**
11	**Astrophysics and Cosmology**	-	-	-	-	-	-	Energy production in stars, Bethe, '67	Pulsars,'74; Cosmic ground radiation,'78	Elements synthesis & evolution of stars, '83	Binary pulsars, Hulse & J.Taylor jr., 1993	Detection of cosmic neutrinos, 2002	**6**

Table 3. Numbers of Physics Nobel prizes laureates (1901-2005) born in (with scientific activities in) different countries

Nr.	COUNTRY	20th CENTURY DECADE										2000-2005	Total 1901-2005
		1901-09	1910-19	1920-29	1930-39	1940-49	1950-59	1960-69	1970-79	1980-89	1990-99		
1	USA	- (1)	- (-)	2 (2)	3 (3)	1 (2)	4 (11)	7 (9)	12 (13.5)	8 (11.5)	13 (16)	9 (11.5)	59 (80.5)
2	GERMANY	3 (3)	4 (4)	3 (3)	1 (1.5)	1 (2)	3 (2)	3 (2.5)	1 (-)	7 (4)	1 (-)	3 (2.5)	30 (24.5)
3	UNITED KINGDOM	2 (2.5)	2 (3)	2 (2)	3 (3)	2 (2)	3 (2.5)	- (0.5)	4 (6)	- (0.25)	-	1 (0.5)	19 (22.25)
4	FRANCE	2 (4)	-	2 (3)	-	-	-	1 (1)	1 (1)	-	1 (2.5)	-	7 (11.5)
5	RUSSIA	-	-	-	-	-	3 (3)	2 (3)	1 (1)	-	-	3 (2.5)	9 (9.5)
6	NETHER-LANDS	2 (2)	2 (2)	-	-	-	1 (1)	-	-	2 (1.5)	2 (2)	-	9 (8.5)
7	SWITZER-LAND	-	-	1 (-)	- (0.5)	-	1 (-)	-	-	2 (3.5)	- (0.5)	-	4 (4.5)
8-9	SWEDEN	-	1 (1)	1 (1)	-	-	-	-	1 (1)	1 (1)	-	-	4 (4)
8-9	JAPAN	-	-	-	-	1 (1)	-	1 (1)	1 (1)	-	-	1 (1)	4 (4)
10	DENMARK	-	-	1 (1)	-	-	-	-	1 (1.5)	-	-	-	2 (2.5)
11	ITALY	1 (0.5)	-	-	1 (1)	-	1 (-)	-	-	1 (-)	-	1 (-)	5 (1.5)
12	INDIA	-	-	-	1 (1)	-	-	-	-	1 (0.25)	-	-	2 (1.25)
13	AUSTRIA	-	-	-	2 (1)	2 (-)	-	-	-	-	-	-	4 (1)
14	CANADA	-	-	-	-	-	-	-	-	-	2 (1)	-	2 (1)
15	IRELAND	-	-	-	-	-	1 (0.5)	-	-	-	-	-	1 (0.5)
16	CHINA	-	-	-	-	-	3 (-)	-	-	-	1 (-)	-	4 (-)
	Other Countries, and Special Mentions[a](see main text)	Poland, Hungary, Luxem-burg, each: 1 (-)	Austra-lia 1 (-)	-	Romania[a] (important results of A. Proca 1936), after Yukawa 1935	-	-	Australia, Hungary, Poland, each: 1 (-)	Hungary, Norway, Pakistan, each: 1 (-)	-	Algeria, Poland, each: 1 (-)	-	Hungary: 3 (-), Austra-lia, Poland: 2 (-), etc
	Average number of laureates/prize	1.5 laureates /prize	1.1 laureates /prize	1.2 laureates /prize	1.4 laureates /prize	1.0 laureates /prize	2.0 laureates /prize	1.7 laureates /prize	2.5 laureates /prize	2.2 laureates /prize	2.2 laureates /prize	3.0 laureates /prize	1.79 laureates /prize
	Average age at the award	49.2 years	48.1 years	45.6 years	42.2 years	51.4 years	49.3 years	50.1 years	54.2 years	59.5 years	60.05 years	66.7 years	53.7 years*
	Average await duration	10.1 years	10.8 years	13.8 years	8.6 years	18.1 years	12.2 years	14.1 years	19.6 years	19.5 years	22.35 years	26.9 years	16.9 years**

* Minimum age at the Physics Nobel Prize award: 25 years (W.L. Sir Bragg, 1915) and maximum age: 88 years (Raymond Davies jr., 2002)

** Minimum await duration from the discovery: 1 year (W.H. Bragg, Lee & Yang, etc) and maximum await duration: 55 years (E. Ruska, 1986)

Table 4

Classification on countries and some specific criteria of the scientific activities accomplished by the Physics Nobel Prize laureates (1901-2005)*

Nr.	Country	Number of active Univer-sities	Number of PhD titles for Physics Nobel Pr. laureates	Number of Master titles for Physics Nobel Pr. laureates	Number of Bachelor titles for Physics Nobel Pr. laureates	Number of post-doctoral Physics Nobel Pr. laureates activity years	Number of points corresp. to Universi-ties*	Number of post-doc.years of PNP win.acti-vities in industry/ govern. institutes	Total number of points** (Univ.+ Industry &Govern Institut.)
1	USA	63	67	29	53	3012	3986	628	4614
2	Germany	30	29	3	10	709	1044	173	1217
3	Unit. Kingd.	13	16	11	19	840	1112	64	1176
4	Russia	12	8	3	6	549	662	43	705
5	France	13	11	-	9	427	564	84	648
6	Netherlands	5	7	3	7	248	354	20	374
7	Switzerland	2	6	1	3	80	154	285***	439***
8	Sweden	4	3	-	2	95	131	76	207
9	Denmark	1	2	2	-	95	125	87	212
10	Japan	4	3	2	3	107	156	13	169
11	Italy	6	4	-	-	40	80	-	80
12	Canada	4	2	2	3	38	77	2	79
13	India	3	-	2	1	31	44	32	76
14	Ireland	3	-	1	1	56	64	-	64
15	Austria	4	2	-	-	38	58	-	58
16	Australia	1	-	1	-	24	29	-	29
17	Ukraine	4	1	-	-	10	20	-	20
18	Poland (Breslau → Wroclaw)	1	1	-	-	3	13	-	13
19	China	3	-	1	2	-	11	-	11
20	Pakistan	1	-	1	-	3	8	-	8
21	Norway	1	-	-	1	-	3	1	4
22	Israel	1	-	-	1	-	3	-	3
23	Czech Rep.	1	-	-	-	1	1	-	1
24	Belgium	-	-	-	-	-	-	1	1
	TOTAL	180	162	62	115	6406	8699	1509 (17% rel. to Universities)	10,208

* Only the identified scientific & didactic activities are synthesized by this Table

** 1 Bachelor degree = 3 points

1 1 Master degree = 5 points

1.1 1 PhD degree = 10 points

1 year of postdoctoral activities = 1 point

*** Majority belonging to international institutions (CERN - Geneva, IBM Zürich research laboratory, Rüschlikon, etc)

Table 5

Countries classification according to the ratio of the Postdoctoral Activity years of Physics Nobel prizes laureates (1901-2005, see Table 4) to their populations

Nr.	COUNTRY	Number of post-doctoral activity years of Physics Nobel prize laureates (Table 4)	Population (millions inhabitants)*	Number of activi-ty years (years) / population(Minh)
1	DENMARK	182	5.5	33.09
2	SWEDEN	171	9.0	19
3	NETHERLANDS	268	16.4	15.95
4	UNITED KINGDOM	904	60.5	14.94
5	IRELAND	56	4.1	13.66
6	U. S. A.	3640	297.2	12.25
7	GERMANY	882	82.5	10.69
8	SWITZERLAND	80 (only national)	7.5	10.67
9	FRANCE	511	60.5	8.45
10	AUSTRIA	38	8.2	4.63
11	RUSSIA	592	143	4.14
12	CANADA	40	33	1.21
13	AUSTRALIA	24	20.2	1.19
14	JAPAN	120	127.5	0.94
15	ITALY	40	58.5	0.68
16	NORWAY	1	4.6	0.22

17	UKRAINE	10	47.5	0.21
18	CZECH REPUBLIC	1	10.2	0.098
19	BELGIUM	1	10.4	0.096
20	POLAND	3	38.5	0.078
21	INDIA	63	1080	0.058
22	PAKISTAN	3	162.5	0.018
23-24	CHINA, ISRAEL	-	1300	-

* According to: http://en.wikipedia.org/wiki/List_of_countries_by_population

Table 6

Classification of all World Universities and Research Institutions upon their contributions to the Education or Use of some Physics Nobel prizes laureates (1901-2005)[11]

1. University of Cambridge, UK: **11 D + 9 M + 13 B + 408 AY =** 602 p; 2. Harvard University, Mass., USA: **9 D + 7 M + 5 B + 358 AY =** 498 p; 3. Columbia University, NY, USA: **11 D + 4 M + 4 B + 259 AY =** 401 p; 4. Princeton University (Institute for Advanced Studies, incl.), New Jersey, USA: **6 D + 3 M + 294 AY =** 369 p; 5. Stanford University (Linear Accelerator Center = SLAC, incl.), California, USA: **2 D + 1 B + 341 AY =** 364 p; 6. University of Chicago, Illinois, USA: **8 D + 2 M + 4 B + 230 AY =** 332 p; 7. Phys. Inst. "P. N. Lebedeva", Moscow, Russia: **3 D + 292 AY =** 322 p; 8. California Institute of Technology (Caltech), USA: **6 D + 4 B + 235 AY** = 307 p; 9. University of California, Berkeley, USA: **3 D + 1 B + 245 AY** = 278 p; 10. Massachusetts Institute of Technology (M. I. T.), USA: **6 D + 4 B + 195 AY** = 267 p; (i) Bell Telephone Laboratories, N. J., USA: 227 AY & p; 11. Cornell University, Ithaca, NY, USA: **1 D + 1 M + 2 B + 175 AY** = 196 p; 12. University of Berlin, Germany: **6 D + 1 B + 125 AY** = 188 p; 13. University of Paris IV, Sorbonne, France: **4 D + 4 B + 115 AY** = 167 p; (ii) CERN, Geneva, Switzerland: 141 AY & p; 14. Moscow State University, Russia: **3 D + 2 M + 2 B + 91 AY** = 137 p; 15-16. University of Leiden, Netherlands: **4 D + 2 B + 90 AY and:** University of München, Germany: **6 D + 76 AY,** both 136 p; (iii) IBM Zürich Research Laboratory, Rüschlikon, Switzerland: 134 AY & p; 17. École Normale Supérieure, Paris, France: **3 D + 3 B + 88 AY** = 127 p; 18. University of Copenhagen, Denmark: **2 D + 2 M + 95 AY** = 125 p; 19. University of Göttingen, Germany: **5 D + 1 M + 64 AY** = 119 p; (iv) Max Planck Institute, Heidelberg & Garching, Germany: 112 AY & p; 20. University of Heidelberg, Germany: **3 D + 81 AY** = 111 p; 21. Imperial University of Tokyo, Japan: **2 D + 1 M + 2 B + 68 AY** = 99 p; 22-

[11] Only the identified activities (by the authors of this study) are registered here. In order to accomplish this classification, the following scale was used: 1 activity year (AY) in the respective institution (after the obtainment of the highest scientific degree) = 1 p; PhD degree (D) = 10 p; MS degree (M) = 5 p; BSc degree (M) [all in the considered institution] = 3 p. This table indicates only the institutions with a total number of at least 10 p.

23. Imperial College of Science and Technology, London, UK: **92 AY and:** University of Illinois, Urbana, Champaign, USA: **1 D + 2 M + 1 B + 69 AY, both** 92 p; 24. University of Colorado, Boulder, USA: **1 D + 80 AY** = 90 p; 25. University of Utrecht, Netherlands: **2 D + 3 M + 3 B + 45 AY** = 89 p; 26. Eidgenössische Technische Hochschule (ETH), Zürich, Switzerland: **4 D + 1 M + 3 B + 34 AY** = 88 p; 27. University of London, UK: **2 D + 1 B + 60 AY** = 83 p; 28. Technische Hochschule, München, Germany: **1 D + 2 M + 1 B + 58 AY** = 81 p; 29. University of Amsterdam, Netherlands: **1 D + 68 AY** = 78 p; 30. Collège de France, Paris, France: **1 D + 62 AY** = 72 p; 31-32. University of California, Santa Barbara, CA, USA: **67 AY and:** "Ioffe" Phys. Techn. Institute, Sankt Petersburg (Leningrad), Russia: **2 D + 47 AY, both** 67 p; 33-35. University of Bristol, UK: **1 B + 63 AY,** University of Würzburg, Germany: **1 D + 56 AY, and:** University of Zürich, Switzerland: **2 D + 46 AY, all** 66 p; 36. University of Edinburgh, Scotland, UK: 64 AY & p; 37. Royal Institution of Great Britain, UK: 61 AY & p; 38. University of Uppsala, Sweden: **1 D + 1 B + 47 AY** = 60 p; (v) Brookhaven National Laboratory (BNL), Upton, NY, USA: 56 AY & p; 39. Moscow Institute for Physics & Technology, Russia: **1 M + 50 AY** = 55 p; 40. University of Michigan, Ann Arbor, USA: **1 D + 1 M + 2 B + 33 AY** = 54 p; (vi-vii) National Institute of Standards & Technology (NIST), Boulder, USA **and:** Bureau International des Poids et Mesures, Sèvres, Paris, France, both 53 AY & p; 41. Technische Hochshule, Berlin, Germany: **2 D + 2 B + 25 AY** = 51 p; 42-45. University of Pennsylvania, Philadelphia, USA: **1 D + 38 AY,** University of Yale, Connecticut, USA: **3 D + 1 B + 15 AY,** University of Gröningen, Netherlands: **1 B + 45 AY, and:** University of Manchester, UK: **2 M + 38 AY, all** 48 p; (viii) Theoretical Physics Institute, Copenhagen, Denmark: 48 AY & p; 46-47. University of Strasbourg, France: **1 D + 37 AY,** Imperial University of Kyoto, Japan: **1 M + 1 B + 39 AY, both** 47 p; 48. Royal Institute of Technology, Stockholm, Sweden: **1 D + 36 AY** = 46 p; 49. Trinity College, Dublin, Ireland: **1 M + 40 AY** = 45 p; 50-51. Brown University, Rhode-Island, USA: **42 AY and** Physikalish-Technische Reichanstalt, Berlin-Charlottenburg, Germany: **1 D + 1 B + 29 AY, both** 42 p; (ix) General Electric Comp., USA: 41 AY & p; (x) Nordic Institute for Theoretical Atomic Physics, Copenhagen, Denmark: 39 AY & p; 52. Mc Master University, Hamilton, Ontario, Canada: 38 AY & p; 53. University of Washington, Seattle, USA: 37 AY & p; 54. University of Oxford, United Kingdom: **2 D + 2 B + 10 AY** = 36 p; (xi-xii). Joint Institute for Laboratory Astrophysics, Boulder, USA **and:** International Business Mach., J. T. Watson Res. Center, Yorktown Heights, NY, USA, both 35 AY & p; 55-56. University of Bonn, Germany: **34 AY and:** University of Hamburg, Germany: **1 D + 24 AY, both** 34 p; (xiii) Siemens&Halske AG, Berlin, Germany: 34 AY & p; 57-58. University of Leipzig, Germany: **1 D + 22 AY and:** École Polytechnique de Palaiseau, Paris, France: **32 AY, both** 32 p; 59. University of Grenoble, France **and:** (xiv) Unified Institute of Nuclear Researches, Dubna, Russia, both 31 AY & p; 60-62. John Hopkins University, Baltimore, Maryland, USA: **30 AY,** Carnegie Institute of Technology, Penn-sylvania, Pittsburgh, USA: **1 D + 1 M + 1 B + 12 AY, and** University of Liverpool, UK: **1 D + 1 B + 17 AY, all** 30 p; 63. University of Adelaide, Australia: **1 M + 24 AY and:** (xv) Manhattan & Los Alamos projects, USA: **29 AY, both** 29 p; 64-65. University of Toronto, Canada: **2 D + 1 M + 1 B and:** University of Pennsylvania, Philadelphia, USA: **1 D + 1 M + 1 B + 10 AY, both** 28 p; 66. University of Roma, Italy: **1 D + 17 AY and:** (xvi) Royal Swedish Academy of Sciences, Stockholm, Sweden: **27 AY, both** 27 p; 67-68. University of Vienna, Austria: **1 D + 16 AY,** Texas A & M University, Texas, USA **and: (xvii)** Digital Pathways Inc., California, USA: **26 AY, all** 26 p; 69. University of Minnesota, USA: **1 D + 1 M + 10 AY** = 25 p; 70-73. University of Wisconsin, Milwaukee, USA: **2 M + 2 B + 8 AY,** University of Graz, Austria, University of Frankfurt, Germany, and P. L. Kapitza Institute for Physical Problems, Moscow, Russia: **1 D + 14 AY, all** 24 p; 74. University of California, San Diego, USA: 23 AY & p; 75-79. University of Lund, Sweden: **1 D + 12 AY,** University of California, Irvine, USA, State University of New York, Stony Brook, NY, USA, Freie Universität, Berlin, Germany, Gorky Niznyi-Novgorod University, Russia, **(xviii)-(xix):** Raman

Research Institute, Bangalore, India, and: Alexander von Humboldt Foundation, Germany: **22 AY, all** 22 p; 80. École Supérieure Muncipale de Physique et Chimie, Paris, France: 21 AY & p; 81-85. New York University, USA, University of Pisa, Italy: **2 D,** Fordham University, NY, USA, University of Texas, Austin, USA, **and:** Institut de Radium, University of Paris, France: **20 AY, all** 20 p; 86-87. Washington University, St. Louis, Missouri, USA, Scuola Normale Superiore, Pisa, Italy, **and** (xx). Centre National de la Recherche Scientifique (CNRS), Paris, France: **all** 19 p; 88-89. University of Bordeaux, France: **1 D + 8 AY,** Duke University, North Carolina, USA: **1 D + 1 M + 3 AY, both** 18 p; 90-92. University of Calcutta, India, Dublin Institute for Advanced Studies, Dublin, Ireland, Moscow Technical University for Steel and Alloys, Moscow, Russia, **and:** (xxi). Texas Instruments, Dallas, USA: 16 **AY** & p; 93.

Indian Institute of Science, Bangalore, India, (xxii)-(xxiii). British Atomic Energy Project, UK, British Thomson-Houston Co., Rugby, United Kingdom: all **15 AY = 15 p**; (xxiv) American Science & Engineering Corporation (ASE), USA: **14 AY = 14 p**; 94-103. Presidency College, Madras, India: **2 M + 1** B, École des Ponts et Chaussées, Paris, France, University of Milan, Italy: 1 D + 1 B, University of Wroclaw (←Breslau), Poland**: 1 D + 3 AY**, Florida State University, USA, University of California, Los Angeles, USA, Case Institute of Technology, Cleveland, Ohio, USA, University of Sussex, Brighton, UK, University of Kiel, Germany, University of Tübingen, Germany**: 13 AY**, all **13 p;** 104-106. University of Stuttgart, Germany**: 1 D + 2 AY**, University of Giessen, Germany, Technische Hochschule, Aachen, Germany, (xxv) Nobel Institute of Physics, Stockholm, Sweden: **12 AY**, all **12 p;** 107. University Paris-Sud, Orsay, France, (xxvi-xxvii). Teyler Laboratory, Haarlem, Netherlands, Centralab, Milwaukee, Wisconsin, USA: 11 **AY, all 11** p; 108-116. University of Massachusetts, Armherst, USA, Rensselaer Polytechnic Institute, NY, USA, Rochester University, NY, USA, Harkov Institute of Mechanics, Ukraine, Osaka University, Japan, Tokai University, Japan: 1 D, University of Texas, Dallas, USA, City College, New York, USA, Hanover Institute of Technology, Germany, (xxviii)-(xxxi). Fermi National Laboratory, Batavia, Illinois, USA, Shockley Transistor Lab. Company & Unit, USA, Cavendish Laboratory, UK, Indian Finance Department, India: **10 AY**, all 10 p.

Table 7.

Main features of scientific activities of the Physics Nobel Prizes laureates with Engineering studies (and/or studies in Technical Universities)

Nr.	**Laureate name & award year of Physics Nobel prize**	**Level of the Engineering studies**	**Main accomplishments**
1: 1st	Röntgen, Wilhelm Conrad, 1901	Eng., Eidgenösische Technische Hochschule, Zürich, 1868	X rays discovery (Würzburg, 1895)
2: 4th	Becquerel, Antoine Henry, 1903	Eng. (1877), Dr. Eng. (1888), École des Ponts et chaussées, Paris	Natural radioactivity (Paris, 1896)
3: 10th	Michelson, Albert Abraham, 1907	Alumni of the Navy Academy of USA, Maryland, 1873	Michelson's interfero-meter & Mich.-Morley experiment, 1887
4: 16th	Dalén, Nils Gustaf, 1912	Eng.: Chalmers Tekniska Högskola, Göteborg, 1896 & ETH Zürich, 1 year	Automatic regulators and Gas Accumulators for lighthouses&buoys

5: 24th	Guillaume, Charles-Édouard, 1920	PhD Eng.: Eidgenösische Tech-nische Hochschule, Zürich, 1883	Metrology materials: invar, elinvar,etc, 1899
6: 25th	Einstein, Albert, 1921	Eng., Eidgenösische Technische Hochschule, Zürich, 1900	Theories of: relativity & gravitation, photoelectric effect, stimulated emission, Einstein - de Haas exp., Bose - Einstein statistics
7: 39th	Dirac, Paul Adrien Maurice, 1933	BSc Electrical Engineering, University of Bristol, 1921	New productive forms of the atomic theory 1928, 1930 (with E. Schrödinger)
8: 40th	Chadwick, Sir James, 1935	Postuniv.: Physikalisch-Tech-nische Reichanstalt, Berlin, 1914	Experimental disco-very of neutron, 1932
8: 41st	Anderson, Carl David, 1936	B.Sc. (1927) & PhD (1930): Caltech, California, USA	Experimental disco-veries of positron, 1932 & lepton μ, 1937
10: 55th	Cockroft, Sir John Douglas, 1951	M. Sc.Techn.: University of Manchester, 1922	Artificial Transmutation of Atomic Nuclei, 1932
11: 62nd	Lamb, Willis Eugene jr., 1955	B. Sc. Chemistry: Univ. of California at Berkeley, 1934	Fine structure of H spectrum, 1947
12: 63rd	Kusch, Polycarp, 1955	B. Eng.: Case Institute of Technology, Ohio	Accurate determina-tion of $\mu_{electron}$, 1948
13: 64th	Shockley, William Bradford, 1956	Eng.: Caltech, 1932; PhD Eng.: MIT, Cambridge, Mass., 1936	Design (with phys. John Bardeen and W. H. Brat-tain) of transistor, 1948
14: 74th	Glaser, Donald Arthur, 1960	B. Eng.: Case Inst. Technol., Ohio, 1946; PhD Eng.: Caltech, 1950	Invention of the cham-ber with bubbles, 1952
15: 76th	Mössbauer, Rudolf Ludwig, 1961	B. Eng. (1952), M. Eng. (1955), Dr. Eng. (1958): Technische Hochschule, München, Germany	Mössbauer effect, 1958
16: 78th	Wigner, Eugene Paul, 1963	Eng. Chem.(1924), Dr. Eng.(1925) Technische Hochschule, Berlin	Theory of atomic nucleus and elemen-tary particles (1931→)
17: 81st	Townes, Charles Hard, 1964	Dr. Eng.: Caltech, 1939	NH_3 maser, 1954 (experimental part)
18:	Feynman, Richard Philips,	B. Eng.: MIT,	Quantum electro-dynamics

86th	1965	Cambridge, Mass., 1939	(1947→)
19: 90th	Gell-Mann, Murray, 1969	Dr. Eng.: MIT, Cambridge, Mass., 1951	Classification of elementary particles and fundamental interactions
20: 93rd	Gabor, Dennis, 1971	B. & Dr. Eng.: Technische Hoch-schule, Berlin-Charlottenb., 1927	Invention of holography, 1948
21: 96th	Schrieffer, John Robert, 1972	B. Eng.: MIT, Cambridge, Mass., 1939	BCS theory of super-conductivity, 1957
22: 97th	Giaever, Ivar, 1973	B. Eng.: Norway Inst. Technol., 1952; Dr. Eng.: Rensselaer Poly-technic Inst., New York, 1964	Experim. Discovery of tunneling in semi- & superconductors, 1960
23: 104	Rainwater, Leo James, 1975	B. Eng.: Caltech, 1939	Combined nuclear model, 1950
24: 105	Richter, Burton, 1976	B. Eng. (1952), Dr. Eng. (1956): MIT, Cambridge, Mass., USA	Discovery of ψ/J particle→ charm quark
25: 110	Kapitza, Piotr Leonidovich, 1978	B. Eng.: Polytechnic Institute Sankt-Petersburg, 1918	Liquid He super-fluidity, 1938 & thermo-nuclear plasma (Tokamak), 1970
26: 112	Wilson, Robert Woodrom, 1978	Dr. Eng.: Caltech, 1962	Discovery of cosmic microwave background radiation, 1978
27: 117	Fitch, Val Longsdon, 1980	B. Eng.: Univ. Mc Gill, Montreal, Quebec, Canada	Violation of fundamental symmetries principles in neutral K mesons disintegration, 1964
28: 120	Siegbahn, Kai Manne Boerge, 1981	Dr. Eng.: Royal Technological In-stitute, Stockholm, Sweden, 1944	Development of the high-resolution electronic spectroscopy, 1957
29: 121	Wilson, Kenneth Geddes, 1982	Dr.: Caltech, 1961	Theory of critical pheno-mena in connection with phase transitions, 1971
30: 123	Fowler, William Alfred, 1983	Phys. Eng.: Ohio State University, 1933; PhD: Caltech, 1936	Formation of the chemical elements in Universe by star explosions, 1957
31: 125	Van der Meer, Simon, 1984	Phys. Eng.: University of Technology, Delft, 1952	Discovery of W & Z bosons – agents of weak interactions, 1983
32: 126	Klitzing, Klaus von, 1985	Phys. Diplomat: Technical University Braunschweig, 1969	Discovery of the quantum Hall effect, 1969

33: 127	Ruska, Ernst, 1986	Eng.: Technische Hochschule, Berlin, 1931	Electronic Microscope, 1931 … 1937
34: 129	Rohrer, Heinrich, 1986	Eng. (1955) and Dr. Eng. (1960): Eidgenösische Technische Hochschule (ETH), Zürich	Design (with phys. Gerd Binnig) of the scanning tunneling microscope, 1981
35: 131	Bednorz, Johannes Georg, 1987	Dr. Eng.: ETH, Zürich, 1982	Ceramic Superconductors with high critical temperature, 1986
36: 132	Müller, Karl Alexander, 1987	M. Eng. (1952), Dr. Eng. (1958): ETH, Zürich	Ceramic Superconductors with high critical temperature, 1986
37: 137	Paul, Wolfgang, 1989	M. Sci. (1937) and PhD (1939): Technische Hochschule, Berlin	Development of the ion trap technique, 1954
38: 139	Kendall, Henry Way, 1990	PhD: Massachusetts Institute of Technology (MIT), 1955	Development of the quark model, 1968
39: 142	Charpak, Georges, 1992	Eng.: École des Mines, Paris, 1948	Invention and development of particle detectors, in particular the multiwire propor-tional chamber, 1968
40: 147	Reines, Frederick, 1995	M. Eng.: Stevens Institute of Technology, N. J., 1939	Detection of the (elec-tronic) neutrino, 1956
41: 148	Perl, Martin Lewis, 1995	Chem. Eng.: Brooklyn Polytech-nic Institute, New York, 1948	Discovery of the tau lepton, 1975
42: 150	Osheroff, Douglas D., 1996	B. Sc.: Caltech, 1967	Discovery of super-flui-dity in helium-3, 1971
43: 151	Richardson, Robert C., 1996	B. Physics & Electr. Eng.: Virgi-nia Polytechnic Institute, 1960	Discovery of super-flui-dity in helium-3, 1971
44: 154	Phillips, William D., 1997	PhD: Massachusetts Institute of Technology, Cambridge, US, 1976	Development of methods to cool and trap atoms with laser light, 1988
45: 155	Laughlin, Robert B., 1998	PhD: Massachusetts Institute of Technology, Cambridge, US, 1979	Theory of the fractional quantum Hall effect, 1983
46: 160	Alferov, I. Zhores, 2000	Electr. Eng.: Leningrad Electro-technical Institute, 1952 & PhD in technology, Ioffe Phys. Techn. Inst. Leningrad, 1961	Development (with phys. H. Kroemer) of semicon-ductor hetero-structures used in high-speed and optoelectronics

47: 162	Kilby, Jack S., 2000	Electr. Eng.: University of Illinois, 1947; M. Electr. Eng.: University of Wisconsin, 1950	Invention of the integrated circuits, 1958 (TI, Dallas)
48: 163	Cornell, Eric A., 2001	PhD (Physics): Massachusetts Institute of Technology, 1990	Achievement of Bose-Einstein condensation in dilute gases of alkali atoms, 1995
49: 164	Ketterle, Wolfgang, 2001	MS: Technical University München, 1982	Achievement of Bose-Einstein condensation in dilute gases of alkali atoms, 1995
50: 165	Wieman, Carl E., 2001	B.Sc.: Massachusetts Institute of Technology (MIT), 1973	Achievement of Bose-Einstein condensation in dilute gases of alkali atoms, 1995
51: 166	Davis, Raymond jr., 2002	Chem. BSc (1938), Phys. Chem. PhD (1942): Univ. of Maryland	Contributions to astrophysics & detection of cosmic neutrinos, 1971
52: 176	Hall, John L., 2005	BSc (1956), MS (1958), PhD (1961): Carnegie Institute of Technology, Pittsburgh, PA, US	Development of the laser-based precision spectrometry & optical frequency comb. technique, 1972..84

Average percentages of the Physics Nobel Prize laureates who had Engineering studies, or who studied in some Technical Universities, on decades

23.1% (1901-1909), 10% (1910-1919), 16.7% (1920-1929), 27.3% (1930-1939), 0% (1940-1949), 20% (1950-1959), 35.3% (1960-1969), 28% (1970-1979), 50% (1980-1989), 36.4% (1990-1999), 38.9% (2000-2005), and:
29.3% = the general (average) percentage for the whole interval 1901-2005

Table 8.

Families of Physics (or Chemistry) Nobel prizes laureates and of fellows of some important Sciences Academies (Nobel prizes awarded between 1901-2005)

1. Antoine César Becquerel (1788-1878), president of the Academy of sciences from Paris 1838), father of Alexandre Edmond Becquerel (1820-1891), president of the Academy of sciences from Paris (1838), father of **Antoine Henri Becquerel** (1852-1908), **Physics Premiul Nobel laureate (1903),** father of Jean Antoine Edmond Marie Becquerel (1878-1953), physicist (researcher).
2. **Pierre Curie** (1859-1906), the husband of **Marie Curie** (b. Sklodowska, 1867-1934), both laureatea of the Physics Nobel Prize (1903), and of the Chemistry Nobel prize (1911, only Marie Curie), resp., parents of **Irène Joliot-Curie,** and parents-in law of **Frédéric Joliot-Curie,** resp., both laureates of the Nobel Prize for Chemistry (1935).

3. **W. H. Sir Bragg** (1862-1942), father of **W. L. Sir Bragg** (1890-1971), both laureates of the Nobel Prize for Physics (1915).
4. **J. J. Sir Thomson** (1859-1940, Nobel Prize for Physics - 1906), father of **G. P. Sir Thomson** (1892-1975, Nobel Prize for Physics in 1937).
5. **N. H. D. Bohr** (1885-1962, laureate of Physics Nobel prize in 1922), father of **Aage N. Bohr** (b. 1922, Nobel Prize for Physics - 1975).
6. **K. M. G. Siegbahn** (1886-1978, Physics Nobel prize in 1924), father of **K. M. B. Siegbahn** (b. 1918, Nobel prize for Physics in 1981).
7. **C. V. Sir Raman** (1888-1970, Physics Nobel prize in 1930), uncle of **S. Chandrasekhar** (1910-1995, Nobel prize for Physics in 1983).
8. **C. J. Davisson** (1881-1958, Nobel prize for Physics in 1937), married with Charlotte Sara Richardson, sister of **O. W. Sir Richardson** (1879-1959, Physics Nobel prize in 1928).
9. **C. H. Townes** (b. 1915, Physics Nobel prize in 1964), brother in law of **A. L. Schawlow** (1921-1999, Nobel prize for Physics in 1981).
10. **J. D. Van der Waals** (1837-1923, Physics Nobel prize in 1910), father of Johannes Diderik Van der Waals jr., who followed to his father at the Physics chair of Univ. of Amsterdam (from 1908).
11. **Frits** (Frederik) **Zernike** (1888-1966, Physics Nobel prize in 1953), brother of the grand-mother of Gerardus ‘t Hooft (b. 1946, Physics Nobel prize in 1999).

Total: 22 laureates of the Nobel prizes, among whom 20 laureates of Nobel prizes for Physics, and 2 laureates of the Nobel prize for Chemistry, identified as relatives between them or with another outstanding professors (from the 177 laureates of the Physics Nobel prizes between 1901-2005).

Table 9.

Physics Nobel Prize laureates of noble origin (year of Physics Nobel prize award) and their academic studies

1. L. V. P. R. **prince** de Broglie (1924), D. Sc. Univ. Sorbonne, Paris, France
2. J. W. S. **lord** Rayleigh (1904), B. A. Cambridge University, UK (i)
3. J. J. **sir** Thomson (1906), B. A. Cambridge University, UK (ii)
4. M. T. F. **von** Laue (1914), Ph. D. University of Berlin, Germany
5. W. H. **sir** Bragg (1915), M. A. Cambridge University, UK (iii)
6. W. H. **sir** Bragg (1915), M. A. Cambridge University, UK (iv)
7. C. V. **sir** Raman (1930), M. A. Presidency College, Madras, India (v)
8. J. **sir** Chadwick (1935), M. S. Manchester University, UK (vi)
9. G. P. **sir** Thomson (1937), B. S. Cambridge University, UK (vii)
10. E. V. **sir** Appleton (1947), B. A. Cambridge University, UK (viii)
11. J. D. **sir** Cockroft (1951), Ph. D. Cambridge University, UK
12. M. **sir** Ryle (1974), B. S. Oxford University, UK (ix)
13. N. F. **sir** Mott (1977), M. A. Cambridge University, UK (x)
14. Klaus **von** Klitzing (1985), Ph. D., University of Würzburg, Germany
15. P. G. **de** Gennes (1991), Ph. D. École Normale Supérieure, Paris, France.