PHYSICS TEACHING IN THE TECHNICAL UNIVERSITIES AND THE PHYSICS EVOLUTION IN THE LAST CENTURY

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Starting from the study of the Physics evolution (as described by the main results obtained in the frame of the Physics Nobel prizes awarded between 1901 and 2005), this work aims to study and point out some possibilities: a) to optimise the choice of the basic Physics topics taught in the frame of technical universities, b) of valuable scientific research accomplished in frame of the best national universities (BNU) that have not had any Physics Nobel prize winners by means of some new important topics, c) of convergence and obtainment of some useful complementary results (relative to the basic results obtained by the Physics mainstream) of the BNU scientific studies accomplished in the frame of some scientific fields with awarded Physics Nobel prizes, d) of improvement of the didactic technologies intended to a better Physics training and understanding by the future engineers.

Keywords: Physics evolution, main results obtained by the works awarded with Physics Nobel prizes, main Physics topics taught in technical Universities, possibilities of the scientific research accomplished by the best national Universities, improvement of didactic technologies.

1 Introduction

The important Physics applications in the technical sciences, biology, medicine, etc. are very well known. Despite these well-known facts, there is a tendency in the technical academic education to reduce to a minimum the Physics teaching and knowledge of students, of the undergraduate cycle, especially. E.g. the academic requirements of the specialty organisations SEFI and CESAER of the European Union [1] for the undergraduate studies (3 years) of all technical faculties stop after the statement "Explain the principles of electric and magnetic fields and apply the basic laws of electric circuits", with the unique additional element "Explain the basic principles of quantum theory". This trend is not a new one: see e.g. the speech of Henry Augustus Rowland, first president of the American Physical Society, at the APS meeting from Columbia University (1899), who underlined the very weak resonance of the majority of the people to most of the results of the "pure sciences". In practice, in the last century only between the 1940-1960 years, corresponding to: a) the 2nd World War, b) the beginning of the use of transistors and c) the building of the first nuclear reactors intended to obtain additional electrical power, did Physics have a rather large "audience" in the technical world.

That is why this work will examine in detail the Physics evolution in the last century, as well as its connection to technical and medical applications.

2 Study of the Physics evolution in the last century and of possibilities to optimize the choice of basic Physics topics taught in frame of technical universities

Taking into account the remarkable importance of the natural sciences, 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. in China alone approx. 181,000 scientific works were published in the Chinese scientific reviews) and – correspondingly – the number of yearly published abstracts of these scientific works is also huge: ~180,000 Physics abstracts/year, ~105,000 Electrical & Electronics abstracts/year, ~100,000 Computer & Control abstracts/year, etc.

As is to be expected, 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 there 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 [2] 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 manufacturing and production engineering, and 5 other main fields of information technology (IT).

Due to the huge number of scientific and technical domains (even of the main domains) and number of 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 are generally recognised for their particular importance. Though we cannot affirm that any scientific result awarded a Nobel Prize is more important than any other result that did not warrant a Nobel Prize, we consider that all the most important scientific (and even technical) results were recognised by Nobel prizes. The Nobel Prize is given as commendation of the achievement deemed to be of greatest benefit to mankind. That is why we will use the brief analysis of the results recognised by Nobel prizes in order to point out: a) the strong connection between Physics, chemistry and the technical sciences, and b) the evolution of the Physics development in the last century. We mention the previous works referring to statistical studies of the Physics Nobel prizes [3], which address complementary topics to the current work, as well as our main sources used for a complete statistical study for the whole interval 1901-2005 [3]-[7].

The results obtained by means of this analysis are synthesised in Tables 1-5, that indicate: the main fields of the research works awarded a Physics Nobel prize (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 classification of universities and scientific research institutions depending on the number of (under)graduate titles (Bachelor, Master and/or Doctors) and the number of activity years accomplished by the Physics Nobel laureates in the frame of these institutions (Table 4), and main results obtained by the Physics Nobel laureates with Engineering studies and/or studies in Technical Universities (Table 5). This last table is particularly poignant in that it shows a great deal of “cross-fertilization” that has occurred between technical universities and/or engineering studies and Physics. Hence solid Physics training bodes well for the future health of Physics.

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

a) topics recognised as important for technical applications by practically all engineers: thermodynamics (2 awarded PNP) and electromagnetism & electromagnetic waves (5 PNP) =

total 7 PNP (all awarded up to 1919), representing approximately 6.31% from the 111 main Physics fields honoured by 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 (8 PNP), condensed matter physics (19 PNP) = total 38 PNP (awarded between 1902 and 2005), representing about 34.23% from the 111 main Physics fields,

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) = total 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) = total 33 PNP, representing also 29.73% of all main PNP topics.

Table 6 presents the physics contribution to a student's education in various countries and schools. The data was gathered from the internet in 2006, some curricular changes might have occurred since then. It is evident that the Physics slice of the curricular pie varies a great deal. Note however, that there is a strong correlation between a) rankings based on web data, b) rankings based on academic or research performance, and c) the percentage of Physics contribution to education.

As it concerns the opinions of the technical universities leaderships relative to the usefulness of the Physics elements teaching in the undergraduate cycle, it seems that there are now three main opinions:

(i) 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 [8]-[10],

(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, (see Table 6)

(iii) the restriction of the Physics elements to be taught in the undergraduate cycle to the topics to aforementioned item a), with very few additional elements concerning the principles of the quantum physics: the opinion of some European organisations [1].

Of course, it is not easy to decide which of these educational policies is the optimal one for a student, for the student's university, or the country supporting the student. It seems that the most important question remains: are the undergraduate alumni over-specialised engineers, or under-educated ones?

3 Study of the valuable scientific results obtained by the BNU universities in frame of some new Physics topics

The competitive landscape for a graduate from a technical university is becoming more difficult: many jobs now see applications from a wider group of people: more diverse and more globally oriented. How is the current student and a future job applicant going to distinguish themselves? Choosing a highly ranked university or choosing a highly specialized and unique program at a less highly ranked university are the common ways of optimizing for the student. University rankings are based on web data, or by scholarly records (such as articles in Science and Nature). Table 4 presents the 180 universities and research institutions with activity points in the frame of PNPs (1 activity year in the respective institution - after the obtainment of the highest scientific degree - = 1 point; PhD degree = 10 p; MS degree = 5 p; BSc degree - all in the considered institution - = 3 p). Comparing the various rankings and Table 4, we see a strong correlation between rankings and PNPs. Hence the advisability and desirability of improving one's ranking based on scholarly productivity: it will attract (more and better) students, (better) faculty, and (increased) funding.

A total worldwide number of 180 universities contributed to the scientific preparation and activity years of the PNP laureates between 1901-2005. This raises a second question for this work: What can the contribution be to the mainstream of Physics of some of best national universities (BNU), that are not (at least, now) involved in the above list of 180 universities or how to improve one's rankings?

Because from Table 4, it follows also that many of the highest classified universities had (and have) strong research institutions involved in their structure, or they cooperate strongly with such institutions,[1] it seems that the contributions at the Physics mainstream of BNU could consist in: 1) results obtained in cooperation with some strong local research institutions,[2] 2) results obtained in some "new" Physics topics area, not yet awarded with PNP,[3] 3) published works corresponding to important results obtained in frame of BNU, located in the field of already awarded PNP: (i) before the PNP award, (ii) after the PNP award, but completing the previously found and recognised results.

In order to avoid some "repetitions", the scientific activities of some professors of BNU universities, already mentioned in certain reference sources (e.g. [7]), will not be cited again in frame of this work.

Referring to the first type - corresponding to the above item a) - of Physics mainstream works (published in international ISI reviews), we have to mention the already existing such cooperation, as those between (e.g.) the Physics Departments of: (i) Politecnico di Torino (Italy) and the National Institute for Electrical Engineering "Galileo Ferraris" (Turin), (ii) University "Politehnica" from Bucharest and the National Institute for Atomic Physics (IFA, Măgurele-Bucharest), etc.

As examples of the second type, we can cite the studies in frame of: a) Biophysics, accomplished at: (i) PSU (referring mainly to the dynamics of Ca++ channels [13]), (ii) University of Kent at Canterbury (in the field of applied (medical) optics [14]), (iii) Politecnico di Torino, in frame of non-destructive testing & examinations and of theoretical biology [15], also in frame of the study of cancer growth [16], etc)], b) nanotubes [17], c) computational physics [18], [19], advanced laser technologies [20] and d) non-conventional energy sources [21], both at University "Politehnica" from Bucharest (UPB).

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[1] See the recent ascension of the University of Colorado, at Boulder, that was completely missing in 2000 in the list of the universities with contributions to the scientific preparation and activity years of some PNP laureates, and it arrived this year (2005) – due to the strong cooperation with the National Institute for Standards and Technology (NIST) and the Joint Institute for Laboratory Astrophysics (JILA) [both from Boulder] - in the top (as the 24th from a total of 180 classified Universities, Table 5) of the worldwide best universities from the PNP point of view criterion.

[2] A very efficient cooperation corresponds to the participation of some BNU professors to the activity in frame of research groups led by Physics Nobel prize laureates [e.g., prof. Ion M. Popescu (UPB) [11] participated in the interval 1963-1964 to the scientific activities in frame of the Hertzian Laboratory of École Normale Supérieure (Paris), directed by Prof. Alfred Kastler (PNP laureate in 1966)].

[3] The physicists (professors and researchers) from the technical Universities, especially, have to avoid the wrong orientations pointed out by paper [12]: "You cannot deny that Physics is central for the development of society, but unfortunately far more physicists possess an arrogant and spoiled attitude where they expect that the surrounding world, in deep respect for the importance of Physics, will rush forward and overwhelm them with large grants. Instead we see that this arrogance causes the grants to go to subjects other than Physics".

4 Possibilities of obtainment of useful complementary results and of convergence of the BNU studies accomplished in frame of some scientific fields with awarded Physics Nobel prizes

A rather well-known example (at least in Romania) of the above third type is that of the UPB alumni – Alexandru Proca (1897-1955), who predicted [independently of the first prediction done in 1935 by the Japanese professor Hideki Yukawa (1907-1981), Nobel prize for Physics in 1949] also the mesons existence, obtaining[4] additionally (referring to Prof. Yukawa's works) also their evolution equations (see also [22]).

Other possible analyzed objects of this study could refer to the UPB Physics researches in the fields of liquid crystals [23] (Physics Nobel prize awarded in 1991 to Professor Pierre Gilles de Gennes, 1991) and even of complexity features in Physics of materials (study of power laws, limit laws, fractal scaling, etc [24]), in field of the PNP awarded in 1977 to Professor P. W. Anderson. It is possible to affirm that the studies accomplished by such BNU converge (usually, considerably less quick and incomplete, but obtaining some complementary results) to the most important results obtained by the mainstream research.

5 Possibilities of improvement of the didactic technologies intended to improve Physics training and understanding

From the beginning, we have to underline also that – besides their important support offered to the scientific research from the Physics Departments of universities – some important research institutions are also directly implied in the scientific training of the Physics professors and in the Physics education of students. E.g.: a) the Abdus Salam International Center for Theoretical Physics (ICTP) from Trieste, Italy, has very important contributions (by means of its Training and Research in Italian (TRIL) Program [25]) to the scientific research preparation of many Physics professors in several extremely important modern Physics topics (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 subnuclear physics, b) the Institute of Physics of the Polish Academy of Sciences (and Prof. Waldemar Gorzkowski, mainly) had an extremely important role in the building and continuous growth of the most important Physics competitions for high-school students: the International Physics Olympiads [begun in 1967, now at the 35th ed. (Salamanca, Spain) in 2005] [26] and the "First Step to Nobel Prize in Physics" international contest for scientific works of these (high-school) students (begun in 1992/1993, and continued yearly without interruption) [27]. These national and international competitions succeed to ensure (for a limited number of the best high-school students) a very good preparation, with remarkable results following their future training in frame of scientific or technical universities.

To improve the ranking of a university (or a country), it is important to improve the instructional processes: productivity and quality of the students increases, positive feedback can be realized.

As it concerns the possibilities of improvement of the Physics teaching in the technical universities, we consider as necessary the careful study both of the qualitative possibilities, as well as of the quantitative aspects.

So, many recent studies (e.g. [28]) stress the necessity to: a) minimize the cognitive load by limiting the amount of material presented (see also [29]), b) have a clear organizational

[4] *A. Proca:* a) "Sur les équations fondamentales des particules élémentaires", C.R. Acad. Sci. Paris **202**, 1490 (1936); b) "Théorie non relativiste des particules à spin entier", J. Phys. Radium **9**, 61 (1938).

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 the common systems, f) use new educational technology (clickers, peer instruction technique [30].

6 Conclusions

We consider as necessary to pay attention to the rather numerous applications of some recent results of the scientific research (many of them recognized by Physics Nobel prizes awards) in the technical sciences and technologies. That is why, we believe as useful the detailed examinations by the international organizations (such as SEFI, CESAER, ABET) for the academic education of engineers, not only of the minimal requirements for each didactic discipline, but mainly of the optimum (in strong relation to the other curricular demands) requirements, in order to ensure the right equilibrium between the technical abilities of the future (undergraduate) engineer, their possibilities to really understand the physical phenomena that underlie the normal functioning (operation) of technical devices and installations, and their ability to find a job.

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Table 1. Classification of the main fields of the research works awarded by Physics Nobel prizes (between 1901 and 2006) 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 &Electromagnetic Waves (radiation & propagation)	Wireless telegraphy (Radio), 1909		Michelson - Morley experiment (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 '37; c) neutrons, '94			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	Gas densities determination, 1904; atom cooling by means of laser radiations, 1997	Cathodic radiation, 1905, Franck-Hertz, 1925; Jean Perrin, 1926	Compton effect, 1927	X-rays , 1901; Bose-Einstein condensation, 2001	Bohr's atomic model, 1922	Theory of photoelectric effect: Einstein, 1921
6	Theoretical physics (only quantum; relativity & gravitation, only implicitly in 1921, A. Einstein)						Energy Quanta, Planck, 1918; Associated waves: de Broglie, 1924	Relativity & Gravity: 1921 Quantum theory: Heisenberg, '32 Schrödinger, Dirac, '33; Pauli, '45; Born, '54; QED ,1965

Table 1 (continued)

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, 1973	Effects: Mössbauer, 1961; Quantum Hall, 1985; Fractionally quantum Hall, 1998	Liquid Helium: 1913; Antiferro-magnetism, '70; superfluidity, '78; HTC, 1987	Richardson's model of the thermionic emission, 1928; Models of liquid crystals and poly-mers, 1991; superconductors and superfluids, 2003	Liquid Helium: 1962; BCS Theory, 1972; Josephson's effect theory, 1973; Magnetic & disorder-ed systems, 1977; Critical phenomena, 1982
8	Radioactivity and Nuclear Physics	Wilson's cloud chamber, 1927; Automated cloud chamber, 1948	NMR, 1944; High accuracy nuclear magne-tic measure-ments, 1952; Coincidence method, 1954	Main radioactive substances properties: P. & M. Curie, 1903	Radioactivity: Becquerel, 1903; Nuclear reactions with slow neu-trons: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	Cyclotron, 1939; Nuclear plates, Powell, 1950; Bubble chamber, 1960 & 1968; Multiwire propor-tional chamber, 1992	For *e, h* mea-surement, 1923; e^- magnetic momentum, 1943 and 1955; For the study of quarks, 1990	Discovery of electron by means of *the study of electrical conduc-tion in gases*, 1906	Interactions of *p* and nuclei, 1951; Violations of the *P* (1957) and *CP* (1980) symmetry	Discoveries of: *n*, 1935; e^+, 1936 π, 1950; p^-, 1959; *J/ψ*, 1976 *W, Z*, 1984; ν_μ 1988, $\bar{\nu}_e$, ν_K, 1995	Nucleon structure, 1961; classification and interactions of elementary particles, 1969; weak and electromagnetic unification, 1979; quantum structure of electroweak interactions, 1999	Theoretical prediction of mesons, 1949; Discovery of the asymptotic freedom of the strong interaction, 2004
10	Plasma Physics					Ionosphere, Appleton, 1947	Applications of mag-neto-hydrodynamics theory, Alfvén, 1970	
11	Astrophysics and Cosmology	Radio-telescope, 1974		Cosmic X-rays source detection & cosmic neutrinos detection, 2002		Pulsars, 1974; binary pulsars, 1993, cosmic background rad.,1978, 2006	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 (1901-2006)

Nr	PHYSICS FIELD	20th CENTURY DECADE											Tot
		1901-09	1910-19	1920-29	1930-39	1940-49	1950-59	1960-69	1970-79	1980-89	1990-99	2000-05	
1	Thermo-dynamics	-	Real gases '10; Gas accum., '12	-	-	-	-	-	-	-	-	-	**2**
2	Electromagnetism & electro-magn. waves (radiation & propagation)	Xrays,1901 ether hypo-thesis, '07; telegraphy, '09	Heat radiation: '11; Energy quanta, 1918	-	-	-	-	-	-	-	-	-	**5**
3	Optics, microscopy & diffractometry	Lorentz,'02 Michelson, '07; Lippmann, '08	Diffraction X-rays,'14; 3D diffrac-tion law,15	-	electrons/ crystal diffraction ,'37	-	phase contrast microscope 1953	-	Holography, 1971	Electron microscope, 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^- spectroscopy, '81;ionic traps, '89	Neutron spectro-scopy,'94	-	**9**
5	Atomic and Molecular Physics	X-rays, 1901; gas densities determination, 1904; Cathodic radiation study, 1905	-	Photoelec-tric,'21, atomic model,'22 Franck-H. '25; Perrin, 26; Compton eff.,27	-	-	-	Quantum electronics: Ammonia (NH_3) maser, 1964	-	-	Atoms cooling with laser radiation, 1997	Bose-Ein-stein con-densation in dilute gases, 2001	**11**
6	Theoretical physics (only quantum; relati-vity & gravita-tion, implicit '21	-	EM waves energy quantization, 1918	Implicit: relativity & gravity, '21 waves: de Broglie, '24	Quantum 1932; Schrö-dinger, Dirac, '33	Quantum theory: W. Pauli, 1945	Quantum theory: M. Born, 1954	QED 1965	-	-	-	-	**8**
7	Condensed Matter Physics	-	Liquid helium: 1913	Special alloys:, 1920; Richardson model of thermionic emission theory: 1928	-	High pressure pheno-mena, 1946	Transistor 1956	Mössbauer Effect, 1961; Liquid he-lium theory: 1962	Antiferro-magn. '70 BCS,'72; tunneling, '73, magn & disor-der syst., '77, su-perfluid'78	Critical phenomena theory: 1982; Quantum Hall effect: 1985; HTC, 1987	liquid crystals/ polymers: ,91; neu-tron dif-fracttion, '94; fract quant Hall, '98	Semicon-ductor hetero-structures and integrated circuits, 2000	**19**

Table 2(continued)

Nr	PHYSICS FIELD	20th CENTURY DECADE										2000-05	Tot
		1901-09	1910-19	1920-29	1930-39	1940-49	1950-59	1960-69	1970-79	1980-89	1990-99		
8	Radioactivity and nuclear Physics	Radio-activity & radioactive substances properties, 1903	-	Wilson's cloud chamber, 1927	Nuclear reactions with slow neutrons: 1938	NMR, 44 exclusion principle β decay: 1945 auto. cloud chamber, 48	nuclear mag. measure-ments, '52; coin-cidence meth., 54 Cerenkov effect,'58	Nuclear shell struc-ture & ato-mic nucleus &fund. symmetry princeples: ,'63	Combined nuclear structure: 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^+: Ander-son 1936; Cyclo-tron, 1939	e^- magne-tic mo-mentum, O. Stern,1943; Theore-tical prediction of mesons, 1949	Nuclear plates, '50; Interactions p - nuclei, '51; e^- mg. momentum '55; Viola-tions of *P* symmetry, '57; p^-, Chamber-lain, 1959	Bubble chamber, 1960&'68 Structure nucleons, '61; Classif. & interactions of elemen-tary par-ticles, '69	Discoveries of: *J/ψ*, Richter-Ting, 1976; Weak and electro-magnetic interactions unification, 1979	Violation of the CP symmetry, 1980; Discoveries of: *W, Z*, '84; ν_μ ,'88	Quarks, '90; Multiwire proportio-nal cham-ber, 1992; $\bar{\nu}_e, \nu_K$ '95; Quantum struct. electro-weak inter-actions:'99	Discovery of the asympto-tic freedom of the strong interaction 2004	**27**
10	Plasma physics	-	-	-	-	Iono-sphere, 1947	-	-	Magneto-hydrodynamic, '70	-	-	-	**2**
11	Astrophysics and cosmology	-	-	-	-	-	-	Energy production in stars, '67	pulsars, '74, cos-mic rad., '78, '06	Elements synthesis/evolution of stars, '83	Binary pulsars, 1993	Cosmic neutrinos detection, 2002	**6**

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

Nr.	COUNTRY	20[th] CENTURY DECADE 1901-09	1910-19	1920-29	1930-39	1940-49	1950-59	1960-69	1970-79	1980-89	1990-99	2000-05	Tot.
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, Luxemburg, each: 1 (-)	Australia 1 (-)	-	Romania[a] (results of Proca 1936), after Yukawa 1935	-	-	Australia, Hungary, Poland, each: 1 (-)	Hungary, Norway, Pakistan, each: 1(-)	-	Algeria, Poland, each: 1 (-)	-	5(-)
	Average number of laureates/prize	1.5	1.1	1.2	1.4	1.0	2.0	1.7	2.5	2.2	2.2	3.0	**1.79**
	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 of all World Universities and Research Institutions upon their contributions to the Education or Use of some Physics Nobel prizes laureates (1901-2005)[6]

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; 22-23. 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, Pennsylvania,**

[6] 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 (B) [all in the considered institution] = 3 p, roman numerals refer to research institutions, Arabic numeral to educational institutions.

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; 117-118. Goethe Gymnasium (University), Frankfurt, Germany:** 3 B, **University of Arizona, USA, (xxxii)-(xxxiii). Kobe Kogyo Corp. Japan, Unidentified Russian research laboratory, where worked G. L. Hertz (1945-1954):** 9 AY, all 9 p; **119-124. University of Maryland, College Park, USA, University of Alberta, Edmonton, Canada:** 1 M + 1 B, **Purdue University, Indiana, USA:** 2 B + 2 AY, **University of Punjab, Lahore, Pakistan:** 1 M + 3 AY, **Whitman College, Walla Walla, Washington, USA:** 1 B + 5 AY, **University of Aberdeen, Scotland, UK, (xxxiv). Metallurgical Laboratory, Univ. of Chicago, Illinois, USA:** 8 AY, all **8 p; 125. USA Naval Academy, Maryland, USA**: 1 B + 4 AY, **(xxxv)-(xxxvii). Fritz Haber Chem. Phys. Lab., Dahlem, Germany, Varian Associates, Palo-Alto, CA, USA, European Space Observatory (ESO), München, Germany:** 7 AY, all **7 p; 126-131. University of Technology, Ohio, USA, State University S. Petersburg, Russia:** 2 B, **Polytechnic Institute of S. Petersburg, Russia:** 1 B + 3 AY, **Leeds University, UK, Innsbruck University, Austria, Technical Physics Institute, Harkov, Ukraine, (xxxviii)-(xliii). Associated Universities Inc., Washington DC, USA, Telecom. Res. Establishment, UK, Deutsche Forschungs-gemeinschaft, Germany, Atomic Energy Research Center (CEA), Saclay, France, Swiss Patent Office, Bern, Switzerland, Gas Accumulator Co., Sweden:** 6 AY, all **6 p; 132-135. University of Oregon, Eugene, USA, Stevens Institute of Technology, Hoboken, New Jersey, USA, Virginia Polytechnic Institute, Blacksburg, USA, University of Tsinghua, China:** 1 M, **(xliv)-(il). RCA Laboratories, Princeton, NJ, Philips Lamp Factory, Netherlands, UK Atomic Energy Authority, UK, UK Naval Department, UK, British Govern. Service, UK, Max von Laue Institut, Grenoble, France:** 5 AY, all **5 p; 136-138. Ohio State University, Columbus, USA: 1 B + 1 AY, Clark University, Worcester, Massachusetts, USA, Marburg University, Germany, (l)-(liv). US Naval Ordnance Lab., Washington DC, USA, Fernseh Gesellschaft, Berlin – Zehlendorf, Germany, Philips Research Laboratory, Eindhoven, Netherlands, Sony Corporation, Japan, Institut Batelle, Geneva, Switzerland:** 4 AY, all **4 p; 139-165. Southern Methodist University (SMU), Dallas, USA; Rice University, Texas, USA; Furman University, S. Carolina, USA; Oberlin College, Ohio, USA; College of Wooster, Ohio, USA; Brooklyn Polytechnic**

Institute, NY, USA; Dartmouth University, New Hampshire, USA; Armherst College, Massachusetts, USA; University of South-Dakota, USA; Augustana College, Rock Island, Illinois, USA; Juniata College, Huntington, Pennsylvania, USA; Mc Gill University, Canada; Münster University, Germany; Technical University Würzburg, Germany; Owens College, UK; Methodist College, Belfort, Ireland; Voronej University, Russia; Electro-technical Institute, S. Petersburg, Russia; École des Mines, Paris, France; Delft Technology University, Netherlands; Chalmers Tekniska Högskola (Univ. of Technology), Göteborg, Sweden; Norvegian Institute of Technology, Trondheim, Norway; Hebrew University of Jerusalem, Israel; South-West National University, Kumming, China; Chekiang National University, China: 1 B, **Sarah Lawrence College, NY, USA; Greifswald University, Germany; Halle University, Germany; Hannover Technische Hochschule, Germany; (lv)-(lvi). US Army Air Force; Monsanto Chem. Comp. Lab., Miamisburg, Ohio, USA:** 3 AY, all **3 p; 166-176. Rütgers University, New Jersey, USA; University of Indiana, Bloomington, USA; Clermond-Ferrand University, France; St. Thomas Gymnasium, Leipzig, Germany; Technische Hoschschule, Karlsruhe, Germany; Firenze University, Italy; Palermo University, Italy; Veterinary College, Vienna, Austria; Polytechnic Institute of Odessa, Ukraine; University of Crimea, Ukraine; I. M. Sverdlov University, Russia** (2 years of teaching of I.Y. Tamm, PhNP-1958); **(lvii)-(lxii). Westinghouse Lamp Co., USA; US Radium Corporation, NY, USA; Argonne National Lab., Illinois, USA; US Atomic Energy Commission, USA; Canadian General Electr. Co., Canada; Dept. Sci. & Ind. Research, London, UK:** all 2 AY & **2 p; 177-180. Jena University, Germany; Landwirstschaftliche Akademie, Hohenheim, Germany; Rostock University, Germany; Prague University, Czech Republic; (lxiii)-(xlix). US Signal Corps, USA; Westinghouse Electr. & Manufacturing Co., USA; Owens Valley Radio Observatory, USA; National Physics Laboratory, UK; High Magnetic Fields Laboratory, Grenoble, France; Francqui Foundation, Belgium; Norwegian Patent Office, Norway:** all 1 AY & **1 p.**

Table 5. 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-Technische 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 determination 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 elementary particles (1931)
17: 81st	Townes, Charles Hard, 1964	Dr. Eng.: Caltech, 1939	NH_3 maser, 1954 (experimental part)
18: 86th	Feynman, Richard Philips, 1965	B. Eng.: MIT, Cambridge, Mass., 1939	Quantum electro-dynamics (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	Electron Microscope, 1931 … 1937
34:	Rohrer, Heinrich, 1986	Eng. (1955) and Dr. Eng. (1960):	Design (with phys. Gerd

129		Eidgenösische Technische Hochschule (ETH), Zürich	Binnig) of the scanning tunneling microscope, 1981
35: 131	Bednorz, Johannes Georg, 1987	Dr. Eng.: ETH, Zürich, 1982	Ceramic superconductors - HTC, 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 proportional chamber, 1968
40: 147	Reines, Frederick, 1995	M. Eng.: Stevens Institute of Technology, N. J., 1939	Detection of the (electronic) neutrino, 1956
41: 148	Perl, Martin Lewis, 1995	Chem. Eng.: Brooklyn Polytechnic Institute, New York, 1948	Discovery of the tau lepton, 1975
42: 150	Osheroff, Douglas D., 1996	B. Sc.: Caltech, 1967	Discovery of super-fluidity in helium-3, 1971
43: 151	Richardson, Robert C., 1996	B. Physics & Electr. Eng.: Virginia Polytechnic Institute, 1960	Discovery of super-fluidity 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 Electrotechnical Institute, 1952 & PhD in technology, Ioffe Phys. Techn. Inst. Leningrad, 1961	Development (with phys. H. Kroemer) of semiconductor 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, per decade

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 6. Physics contributions to the student's education in various countries and universities.

University/Faculty/Source	**World rank***	**Semester 1**	**Semester 2**	**Sem. 3**	**Sem. 4**	**Sem. 5**	**Sem. 6**	**Sem 7**	**Sem 8**	**Physics Total (%)**
University of Pittsburgh (Bachelor Cycle = 4 years) School of Engineering Engineering Physics	**56** USA	4 Credits from 17 total 4 Credits from 17 total	4 Credits from 17 total 4 Credits from 17 total	None 2 PHYS +4? From 16 tot.	-	None 6 cr. from 16 total	None 6 cr from 15 total	None 3 cr +3? elect. / 18 tot	None 3 cr +3? elect. / 15 tot	**23.5% 1^{st} year At least 5.9% from total (School of Engineering)**
Notre Dame University, Indiana (Bachelor Cycle=4yr) Computer Science Computer Engineering	**106** USA	- -	4Cr from 18 tot 4Cr from 18 tot	4Cr / 17.5 tot 4Cr / 17.5 tot	- -	- -	- -	- -	- (130 total) - (130 total)	**22.22% sem.2 & 3 6.15% total**
Portland State University, Oregon (BS Cycle = 4 years) Computer Science Computer &Elec Engineering	**225** USA	**12 Credits from 51 total 12 Credits from 51 total**		In frame of Sciences Electives Approx. 25% from **8 Credits from 48 total**		**- 6 credits from 45 total**		- -	- -	**23.5% 1^{st} year 7.7% from total 9.4% from total 9.6% from total**
Medium level technical USA faculties										**Average 7.37% from total**
Technical University Darmstadt Allgemeiner MaschinenBau	**249** Germany	Solid state (4 credits)		Physik 4 c.p.	Phys Praktik. 3 cr.					
Politecnico di Milano (BS=3 yr) Ingegneria Informatica e on Line Ingegneria elletrica	**470** Italy	**Primo Anno** 10 credits from a total of 50 12.5 credits from a total of 60		**Secundo Anno** - - 5 credits from 60 total		**Terzo Anno** - - - -		**BACHELOR CYCLE FINISHED**		**6.67% from total 9.72% out total**
Politecnico di Torino (BC=3yrs) Ingegneria dell'informazione Ingegneria elettronica Ingegneria fisica	**528** Italy	**Primo Anno** 10 credits from a total of 59 10 credits from a total of 59 12 credits from a total of 61		**Secundo Anno** 3 + 4 (Fond.Meccan.)/55 total- 29 credits from a total of 59		**Terzo Anno** - - 18 cr. +? out of 59		**BACHELOR CYCLE FINISHED**		**9.9% from total 5.7% from total > 35% from total**
Universite de Nantes Ingenieur Sciences des Materiaux	**875** France	Appl. Phys. I (60 h)	Appl. Phys. II (62 h)	Solid State I+II/Stat Phys (84 h)						Approx. **6.33% from total**
Université de Nantes (BC=3 yrs) Ingénieur Génie Électrique	**875** France	E&M:42 hrs +Thermo 42 h out of 430 hrs	Semicond., 26 h + mech. 42 h out of 408 hrs	-	-	-	-	**BACHELOR CYCLE FINISHED**		**6.04% from total**
University of Applied Sciences Brandenburg (prof. Michael Vollmer)	**924** Germany	-	Physik 4C+2S+2L	-	-	-	-			
Technische Universität Braunschweig	**1005** Germany	-	Physik 3 C + 3 L	-	-	-	-			
Cours Preparatoire Polytechnique Greneoble	**1075** France	Mech: 60 h = C+S+L)	Thermo 52 h E&M 52h	electronics 58h waves (60 h)						**14.1% from total**

University/Faculty/Source	World rank*	Semester 1	Semester 2	Sem. 3	Sem. 4	Sem. 5	Sem. 6	Sem 7	Sem 8	Physics Total (%)
Ingenieur de Polytech Grenoble Informatique Industrielle et Instrumentation	**1075** France	General science educ. 280 h: maths/physics		General science educ. 140 h: maths/physics						Approx. **4.5% from total**
Ingegnieur de Polytechnique de Grenoble Spec: Prevention de Risques	**1075** Franta	Fund. science: 371 h (Biologie, Chimie, Info, Physique, Probabilités)		Fund. science:: 132 h (, echanges thermiques, …, mechanique des fluids, …)						Approx. **3.08% from total**
Ecole Supérieure d'Ingénierie en Électrotechnique et Électronique (ESIEE), Noisy le Grand, Paris, Ingénieur ÉSIÉÉ	**2559** France	1-ère Année Phys. (Mécanique du point, Thermodynamique, Électrostatique, Optique géometrique) 150 hrs out of 792 hrs		2-ème Année Phys (Electrocinétique, Électrotechnique, Magnétostatique, Ondes des prop.) 150 hrs out of 834 hrs		3-ème Année NO AVAILABLE INFORMATION		CYCLE MAJEURES 4-ème Année Physics of semicond. devices, ~37.5 hrs		**13.78% from total**
Budapest University of Technology and Economics Faculty of Electrical Engineering and Information Technology Prof. Pal Pacher (SEFI)	**242** Hungary	-	4 lect. hrs/wk, 2 opt. (recit.) hrs/wk Exp. demonstr. at lect 5 cr. EE & 4 cr. IT out of 30	4 lect. hrs/wk2 opt. sem. (recit.) hrs/wk, exp. demonstr. at lect 5 cr. EE & 4 cr. IT out of 30	-	-	-	-	**BS CYCLE FINISHED**	**Electrical engineering 4.76% Information Technology 3.81%**
Technical University from Brno Faculty of Mechanical Engineering (sent information by Prof. Miroslav Dolozilek)	**530** Czech Republic	-	Physics I, 39 hrs lect, 26 hr sem. 13 hrs laborat. Mech.→Thermodynamics	Physics II, 39 hrs lect, 26 hrs sem., 26 hrs laborat., EM. NuclearPhysics	-	-	-	**MASTER CYCLE**		Mech. Eng. 8.3% from total (Bachelor cycle**)**
Technical University from Brno Faculty of Electrical Engineering & Communication (according to TPPE-2005 paper of Prof. E. Hradilova)	**530** Czech Republic	-	Physics I 26 hrs lectures 13 hrs seminars 26 hrs laborat.	Physics II 26 hrs lectures 13 hrs seminars 13 hrs laborat.	Physics Seminar 26 hrs seminars	-	-	**MASTER CYCLE** Modern Physics 3+1+ 0, nondes-tructive diagnostics & phys. of dielectrics 2+ 1 + 1, Nanotech. 2 + 1 + 1		Elect. Eng. 7.06% **(Bachelor cycle)**
Warszaw Univ. of Technology & Technical Univ. from Poland (prof. I. Strzalkowki) BS= 3 yrs	**766** Poland	Physics I	Physics II	Phys III Tot: 90-115 hrs (60…75 hrs lect.)	-	-	-			**3…4% from total**
Best technical universities from Central Europe										**Ave: 5.49% from total**
EPFL: Génie électrique et électronique	**137** Switzer-land	Année Propédeutique Physique Générale Coeff. 1 from 12 total		Phys. III, IV , sem. 3 & 4 10 Credits from a total of 56 credits				**BACHELOR CYCLE FINISHED**		**14 Credits Approx. 9.3%**

University/Faculty/Source	World rank*	Semester 1	Semester 2	Sem. 3	Sem. 4	Sem. 5		Sem. 6	Sem 7	Sem 8	<u>Physics</u> Total (%)
University "Ben Gurion" Negev Faculty of Electrical Engineering and Computer Sciences	<u>448</u> Israel			Min 2 Physics courses, + Modern Physics Course							
University "Politehnica" Bucharest 1) Faculty of Electronics 2) Faculty of Engineering in International Languages FEIL	<u>1758</u> Romania	Phys. I, 3 lect., 1 sem., 1 lab hrs/week	Physics II 3 lectures 1 seminar hours/week	Physics III 2 lectures 1 laboratory hours/week	**FEIL** Same numbers of hrs, but sem. 2 - 4	-	-	-	-	**Bachelor Cycle Finished**	**112 lecture hrs** **28 seminar hrs** **<u>28 laboratory hrs</u>** **Total 168 hrs**
University "Politehnica" Bucharest *1) Faculty of Control Systems and Computers* *2) Electrical Engineering Fac.*	*<u>1758</u>* *Romania*	***Only 1 Physics semester*** ***3 lect., 3 lect., 1 sem, 2 lab.*** ***2 laboratory*** ***Computer Div. Electr. Eng*& Contr. Syst. Div.***		-	-	-	-	-	-	***Bachelor Cycle Finished***	***42 lecture hrs*** ***14 seminar hrs*** ***<u>28 laboratory h</u>*** ***Total:*** ***70…84 hrs***
University "Politehnica" Timişoara *Only 1 Physics teaching semester*	*<u>2182</u>* *Romania*	*(N-2) faculties* *2 lectures + + 1 S + 1 L*	*Faculty of Electronics* *2 lectures + 1 S +1 L*	-	-	-	-	-	-	***Bachelor Cycle Finished***	***28 Lect. hrs*** ***14 Seminar hrs*** ***<u>14 Laboratory hrs</u>*** ***Total 56 Phys. hrs***
University "Politehnica" Timişoara *Fac. Manufacturing & Transp. Management*	*<u>2182</u>* *Romania*	*1 sem only!* *1 C +0S +0L !*	-	-	-	-	-	-	-	***Bachelor Cycle Finished***	***14 Lecture hrs*** ***ONLY 14 Physics hours!***
Technical University Iaşi 1) Fac. of Industrial Chem. (FIC) 2) Faculty of Electronics (FE) 3) Faculty of Civil Eng. (FEC)	<u>2386</u> Romania	Physics I 2 lect., 1 sem. (FE, FEC) 2 lab. hrs/ wk (FIC)	Physics II 3 lect. (FEC) 2 lect. (FIC, FE),2 lab. hrs/ wk (all)	-	-	-	-	-	-	**Bachelor Cycle Finished**	**56…70 lecture hrs** **14 seminar hrs** **<u>56 laboratory hrs</u>** **126…140 total hours**
Technical University Iaşi *1) Faculty of Mechanics (FM)* *2) Faculty of Automations (FA)*	*<u>2386</u>* *Romania*	*2 C+1 L (FM), 3 C+2 L (FA &Comp. Sci.)*	-	-	-	-	-	-	-	***Bachelor Cycle Finished***	***28 C+14 Lab (FM)*** ***42 C + 28 Lab (FA & Comp. Science)***
Technical University Cluj-Napoca Fac. Electronics & Fac. Materials Sci.&Engn.	<u>2550</u> Romania	**Physics I** 2C + 1L	**Physics II** 2C + 1L	-	-	-	-	-	-	**Bachelor Cycle Finished**	**56 Lecture hrs** **<u>28 Laboratory hrs</u>** **Total 70 Physics hrs**
Technical University Cluj-Napoca *Fac. Mechanics, Machines Manufact., & Civil Engng.*	*<u>2550</u>* *Romania*	*1 Physics teaching semester* *2C + 1L*	-	-	-	-	-	-	-	***Bachelor Cycle Finished***	***28 Lecture hrs*** ***<u>14 Laboratory hrs</u>*** ***Total 42 Physics hrs***

University/Faculty/Source	**World rank***	**Semester 1**	**Semester 2**	**Sem. 3**	**Sem. 4**		**Sem. 5**	**Sem. 6**	**Sem 7**	**Sem 8**	**<u>Physics</u> Total (%)**
University "Ştefan cel Mare", Suceava Faculty Electrical Engineering	**<u>3545</u>** Romania	Physics I 2C + 2L	Physics II 2C + 2L (+1S, Comp. Division)	-	-	-	-	-	-	**Bachelor Cycle Finished**	**56 Lecture hrs 56 Laboratory hrs <u>14 Seminar (Comp)</u> Total 112…126 hrs**
University "Ştefan cel Mare", Suceava *Fac. Mechanical Engineering Silviculture Faculty*	***<u>3545</u>*** *Romania*	*Biophysics 2C + 2L Silviculture Faculty*	*2C + 2L + 1S Faculty of Mechanical Engineering*	-	-	-	-	-	-	***Bachelor Cycle Finished***	***28 Lecture hrs 28 Laboratory hrs <u>14 Seminar (ME)</u> Total 56…70 hrs***
University "Lucian Blaga" Sibiu *Engineering Faculty*	***<u>4405</u>*** *Romania*	*Only 1 Physics teaching semester: 2 C + 1 applications*		-	-	-	-	-	-	***Bachelor Cycle Finished***	***28 Lecture hrs <u>14 Seminar hrs</u> Total 42 hrs***
University "Ovidius" Constanța Sections of Electronics & Chem. Engineering, resp.	**<u>5387</u>** Romania	**Physics I** 2C + 1S + 1L	Physics II **2C +1S +1L**	-	-	-	-	-	-	**Bachelor Cycle Finished**	**56 Lecture hrs 14 Seminar hrs <u>14 Laboratory hrs</u> Total 84 Phys. hrs**
University "Ovidius" Constanța *Faculty Mechanics & Faculty Civil Engineering*	***<u>5387</u>*** *Romania*	***2C +1 applics.***	**-**	-	-	-	-	-	-	***Bachelor Cycle Finished***	***28 Lecture hrs <u>14 Application hrs</u> Total 42 Physics hrs***
University for Oil and Gases, Ploieşti Fac. Electrical Engng.	**<u>6657</u>** Romania	-	-	**Physics I 5C + 2S + 2L**	**Physics II 5C + 2S + 2L**	-	-	-	-	**Bachelor Cycle Finished**	**140 Lecture hrs 56 Seminar hrs 56 Laboratory hrs**
University for Oil and Gases, Ploieşti Fac. Oil & Oil Chem.Technol.	**<u>6657</u>** Romania	-	**-**	**Physics (1 Semester) 4C + 1S + 2L**	-	-	-	-	-	**Bachelor Cycle Finished**	**56 Lecture hrs 14 Seminar hrs 28 Laboratory hrs**

* According to the Webometrics 2006 classification: http://www.webometrics.info/

<u>NOTES:</u> 1) The minimum number of Physics teaching hours at the technical universities from the EU countries was found in Germany: 3 C + 3 L at Technical University of Braunschweig (Technische Universität Braunschweig), TUB: 3 C (lectures) + 3 L (laboratory)/2nd academic semester.

2) The technical Universities (or faculties) with Physics teaching hours less than those from TUB, are in *italics* in the Table.