Physics Education in Russian Federation

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Introduction

A former president of Russian Federation (RF) Mr.V.V.Putin in his speech at VII-th Congress of university rectors of RF pointed out that "The high quality of education in Russian Federation is one of the few factors making us a part of leading countries in the world" [1]. First of all the president of RF meant the mathematical and natural scientific education (physics, chemistry, biology). As it follows from the report of the rector of Moscow State university professor Victor Sadovnichij about 100 000 young specialists in Russia are leaving annually their country getting job mainly in Europe and the United States [2]. Most of them are physicists who have got free education in the institutes and universities of RF.

The physics education in Russian Federation is based on the education system of the former Soviet Union. This is different from that of the United States or Europe. A typical educational trajectory of the individual person in Russia is following. General school starts when a child gets seven years old and continues for ten years until a pupil reaches seventeen. The general school in Russia combines American or European elementary school, high school and junior high school. At 17 an adolescent finishes a general school[1] and can enter the university (high education) or college (the secondary specialized education).

The concepts of bachelor and master did not exist in the Soviet education system. The high education in the Soviet system could be obtained within the period of five studying years. The corresponding diploma ascertains that the owner has got a qualification in the particular field (physics, chemistry, applied mathematics, philology etc.). Such graduates are called "specialists". One has to distinguish between the speciality and specialization. Any field of knowledge has a set of corresponding specialities specified by the particular code number: 010400-"Physics", 010100 -"Mathematics", 011000 - "Chemistry", 040100 - "Medicine" etc. [3]. Each speciality may include several specializations.

In the beginning of 1990th Russian education system took a turn towards the international educational space. Since that time the concepts of bachelor and master became a part of Russian high education. The traditional Soviet system is called "the education over the speciality". We shall call it the SU system, which assumes five years long studying time. In contrast with SU system an international system assumes four or six academic years for bachelors and masters correspondingly. In Russia this system is called "the educational direction", or the ED system.

At a present time Russian high education has three different forms: bachelor degree (ED system with 4 studying years), master degree (ED system with 6 studying years, including four bachelor's years), specialist (SU system with 5 studying years). In contrast with the first two, the specialists do not get a degree, but a qualification. The principle difference between the concepts of "bachelors" and "specialists" is that the bachelors get a broader amount of knowledge, but which, however, is not so deep. In contrast with the specialists the bachelors do not have the specialization. The specialists get deeper but more specialized education within some particular branch of studying speciality. On the other hand the masters get broader and, at the same time,

[1] The real total educational time in the general school is ten years, but due to the change of the Russian educational system towards the international one the 10 years system is to be changed by 12 years system. Because of these reasons the 4th grade does not exist in the schools today, i.e. the studying grades are 1st -3rd and 5th - 11th.

deeper education, comparing with that of specialists. These three educational levels, two of which represent ED system and one represents the SU system, are sometimes called in RF as the 1-st level (bachelor), 2-nd level (specialist) and the 3-rd level (master) of high education. The students may get a bachelor degree at the age of 21, the specialist diploma at 22 and the master degree at 23. As a rule about all the students having a bachelor degree in RF continue the education in magistracy. Nowadays 530 specialities and educational directions represent the high education in Russian Federation [3]. There are about 900 educational institutions in RF providing high education for 3 million students.

The problems of physics education in Russia have been discussed in detail at the I Congress of Physics Teachers of RF "Physics Education in the XXI century" in June 2000 [4]. That was for the first time in Russia the physics teachers of general, specialized and high educational levels had been gathered together to determine the common program of development of physics education. It had been noted by many participants that some negative trends in the Russian education system appeared just after the collapse of the Soviet Union. The number of physics hours in the schools had been reduced. The physics education became less fundamental. It was pointed out that physics was the basis of the successful development and defensibility of any country pretended the leading role in the world. The important role of physics education in the general school for forming the correct world outlook of pupils had also been emphasized.

Some important aspects of natural science education, including physics, has recently been discussed at the First and the Second International Congresses "Universities and Society" in Moscow [5,6] (see also [7]).

Physics in the general school.

Physics in the general schools starts at the 7-th grade when a pupil reaches 13 years old and continues for five subsequent years. Up to the 9^{th} grade all the pupils independently on their individual abilities study according to the same program. The last two grades are specialized, i.e. the pupil can choose the class according to his (her) abilities: physics and mathematical class, philological class etc. The basic textbooks in physics, however, are the same independently on the specialization. The books are written in such a way that they contain simultaneously different levels of material presentations. It means, that the pupils studying deeply, for example, the social science, use the same physics textbooks as those studying in physics classes. Of course, physics in the physical classes is studied in more detail.

Besides the basic physics textbooks there are many different ones written by different authors with various degrees of complexity. In the present paper we shall consider only the basic general school textbooks recommended by the Russian Ministry of Education and Science (RME) [8-12]. Also recommended are the books of physics problems. The most commonly used text book, containing the large number of problems with different levels of complexity, is that of Rimkevich A. [13].

The numbers of academic hours[2] per week for physics in an ordinary general schools are: 2 hours at 7^{th} and 8^{th} grades, 2-3 hours at 9^{th} grade and 2 hours at 10^{th} and 11^{th} grades. For classes with physics and mathematics specialization the number of hours per week can be 5-6 or even more (10^{th} and 11^{th} grades). Many universities and institutes in RF begin training the pupils in the general schools to make them future students. Usually such schools have special classes taught at the 10^{th} and 11^{th} grade.

A survey of general school physics is shown in the Tables 1-5. The tables contain the detail information about the content of the general school physics textbooks [8-12]. The names of the chapters are shown in the second column. The third column contains the basic formulas appearing in the textbooks, while the last column shows the amount of the corresponding material with respect to the total content of the given textbook. The notations used in the tables

[2] One academic hour is equal to 45 astronomical minutes.

are the same as those in the textbooks. To shorten the space the formulas are written there as inline inserted ones. It follows from the tables, that during the 7th and 8th grades all the elementary physics is studied. Many of these sections reappear again at 9th-11th grades, but with the higher degree of complexity. According to the new educational system, which is now in the process of being introduced in the Russian general schools, the physics programs for 7th-9th grades are assumed to be common programs for all the pupils independently on their future specialization. Physics is considered as a science, which develops facility in critical thinking, reasoned argumentation and true understanding of the nature phenomena.

Physics textbooks contain the brief biographies of famous physicists, like Newton, Coulomb, Ohm, Faraday, Maxwell, Einstein, Plank and many others. An accent is done on contributions of Russian and Soviet physicists like Mendeleev, Stoletov, Lebedev, Frenkel and others. It is pointed out, for example, that radio communication have been discovered by Russian physicist A.S.Popov in May 7, 1895, and had been improved latter by Marconi [12], who got a Nobel price (together with Brawn) in 1909.

Physics in the system of high education

High education system in RF has some general rules. Any speciality or educational direction is governed by the corresponding Educational and Methodical Council (EMC), which, in collaboration with Russian Ministry of Education and Science, develops the basic document, defining the educational process on particular speciality (or educational direction). This document is called the State Standard of High Professional Education (SSHPE), or simply the educational Standard. The Standards are confirmed by the Ministry of Education and Science of RF. The first generation of SSHPEs had been established in Russian education in 1994. Since 2000th the second generation is in process. The SSHPEs of all the specialities and educational directions are available through the Internet [3].

Any SSHPE contains the following items:

1) General features of the given speciality (or ED);

2) Requirements to the applicants who has chosen the given speciality (or ED);

3) General requirements to the educational program;

4) Requirements to an obligatory minimum of the contents of the given education program;

5) Duration of the educational process;

6) Requirements to the conditions of realization of the given educational program (including the qualification of the teaching stuff);

7) Requirements to the final examination of the graduate (final certification). The final examination includes the state examinations and the defense of the graduation work (the bachelor, specialist or master thesis).

The curriculum is formed by the teaching department of the university or institute mainly in agreement with the items 4) and 5) given above. The amount of studying time is measured in terms of the academic hours and weeks. Is has been assumed, that the student should not study for more than 54 hours per week, i.e. 9 hours per working day. This is due to the biological reasons. The number of class hours should not exceed 36 per week. The hours which a student spends in the classroom are called the auditorium hours, whereas the time during which a student studies by himself (herself) is measured through the self-training hours. The Standards of the most specialities (and EDs) restrict the amount of auditorium hours by 27 per week. The hours of sport exercises (physical culture) and optional disciplines are not included to this 27-hour limit. But, as an exception, the physics Standards permit 32- auditorium hour limit. This is because of the large number laboratory classes in the physics curricula. Unfortunately, the physics educational Standards of the third generation, which have recently been approved by EMC-physics [14], do not contain such the 32-hour requirements. In practice this means that the

specifics of the physics education will not be taken into account any more by the university officials defining the university stuff.

The EMC in physics is located in the Moscow State university [15], and is briefly called the EMC-Physics. As a rule the deans of the physics departments of the leading universities are members of the EMS presidium. They meet at least twice a year to discuss the current problems of high physics education. The EMS-Physics generates recommendations, rules, new physics educational programs etc. for all the high education institutions all over the whole country.

Nowadays ten physics specialities exist in the RF. They are listed in the Appendix 1, where some corresponding specializations are also presented. The total number of specializations belonging to a given physics speciality is shown in the brackets. The last column shows the qualification awarded within the frame of the particular speciality. The same specialization may belong to the different specialities, as well as some specialization may have the same name as some speciality. The role of specialization on the master level is fulfilled by the master programs corresponding to any educational direction. The complete list of master programs is available from [3]. As it has been mentioned above, the educational directions (the ED system) on the bachelor level do not have a specialization.

The set of disciplines defining by the SSHPE for speciality 010400-"Physics" (recently this code number has been changed to 010701) is presented in Appendix 2. All the Standards have a structure of this part similar to that presented in Appendix 2. All the disciplines are divided into five different sections: GSE (General humanitarian and social-economic disciplines, 1800 hours); NS (General mathematical and natural science disciplines, 3440 hours); GPD (General professional disciplines, 1310 hours); DS (Disciplines of specialization, 1532 hours); OC (Optional courses, 450 hours). The Standards of all the mathematical and natural science specialities (and EDs) have the same sections, but with different contents. The hours here mean the total numbers of hours, which include the auditorium hours and the self-training, i.e. the Standards indicate only the total hours, whereas it is up to the teaching departments to divide the total hours to the lectures, practices etc. The number of auditorium hours is proportional to how much does the given educational program cost. The total staff of universities in RF is proportional to the number of students as 1:10, although the stuff of the individual speciality (or ED) depends on the number of auditorium hours.

Appendix 3 illustrates the different types of academic activities and their duration. Only these types of activities are possible. According to the Appendix 3 the total number of hours for theoretical education must be 158 weeks x 54 hour per week = 8532 hours, which is consistent with the Appendix 2.

Each of five sections shown in Appendix 2 contain a federal disciplines and a regional component. The latter is formed by the individual department according to its educational traditions etc. The department forms also the elective courses for each section. The Standard does not define the number of hours for all the disciplines, this is up to the universities. The university can vary the number of hours for each section shown in Appendix 3 within the limit of 10%.

It is not necessary to include all the disciplines of the GSE section listed in an Appendix 2 into the curricula. The only obligatory courses from this section are: the foreign language; physical culture (athletics, sport); the state history and philosophy. The university must include all the disciplines of NS and GPD sections listed in the Appendix 2. Note, that all the physics specialilies listed in Appendix 1 have exactly the same structures as that demonstrated in Appendixes 2 and 3. The difference between them appears only in the DS-section. This section is usually divided by the departments into two approximately equal parts: the disciplines listed in DS section of the Appendix 2 and the DSL disciplines. The DSL subsection may contain up to 5-10 disciplines and is formed by the departments according to the specific features of the individual specialization (some possible specializations are listed in the Appendix 1). The university must choose at least five DS-disciplines from eight, shown in an Appendix 2. The OC section contain the military courses. This is not obligatory for all the students (in the Soviet

Union it was obligatory). Usually about only 10-15 percent of the student contingent can get the high military education and receive a commissioned rank (i.e. to become an officer). The physicists passing through the military education are becoming specialists in military intercommunication. The military education starts at the second year and continues for two subsequent years. Usually the competition among the students to enter the military department of the university is rather high. The military diploma together with the physicist diploma gives some more opportunities in getting job.

The bachelor educational Standard which is similar to that discussed above is called 510400-"Physics" (i.e. the code is the same as that for specialists with the exclusion of the first number, the ED codes have the first number "5", the subsequent numbers are the same as those for specialists). The sections GSE, NS, GPD and OC in the bachelor Standard are exactly the same as those shown in Appendixes 2 and 3. The only difference is in the DS section. Since the specialization does not exist for bachelors the corresponding section is called SD - special disciplines. In contrast with the DS (disciplines of specialization), the SD section of bachelors does not contain the disciplines which all belong to some particular branch of physics science, i.e. SD disciplines may represent absolutely different physical subjects. The bachelor Standard gives 776 hours for SD disciplines, i.e. twice less than the SU Standard gives to DS section. The difference of one year in duration of education for bachelors and specialists comes from the difference in SD and DS sections and also from the fact, that the SU Standard gives 20 weeks for working out the graduation thesis. In contrast with bachelor graduation work, the specialist thesis should contain new scientific results.

The typical curriculum for speciality 010400-"Physics", consistent with the data given in the Appendixes 2 and 3, is presented in the Appendix 4. The first part of the curriculum is called the schedule of the educational process (SEP). Each square in SEP corresponds to one week and represents some particular kind of educational activity: theoretical education, holiday etc. The total educational duration is 260 weeks, which is equivalent to 5 years. It follows from the SEP, for example, that from January 19 to 25 the 1-4 year students have the examination session, whereas the 5^{th} year students have a professional practice.

The curriculum plan (CP, see part 2 in Appendix 4) includes all the disciplines with their volume (in hours) and sequence. There are two types of estimation of the student's knowledge: the examination and the test (sub-examination). The exams have four degrees: excellent, good, fair and bad. The tests have only two possibilities: positive and negative. The number of exams and tests in one semester should not be more than 12. The column 3 in CP shows the semester in which a given subject has an exam, the column 4 shows in which semester it has a test, the column 5 shows the semester in which students must write an undergraduate thesis. Columns 6 - 24 define the hours. Columns 15-24 show the number of auditorium hours per week. Column 9 gives the total number of lecture hours corresponding to given discipline, column 10 is the same, but for laboratories, and column 11 shows the total number of practical classes. Note, that the practical classes in the GSE section are sometimes called "the seminars". The auditorium hours (lectures, practices, laboratories and seminars) are given in the column 8. Column 7 shows the total hours: auditorium + self training (given by column 14). Column 6 shows the total hours given by the SSHPE.

As an example consider the quantum theory (see GPDF.01.5 in the CP). According to the columns 3 and 4 this discipline has an exam in the 7^{th} semester (which starts January 5, see the SEP) and the test in the 6^{th} semester. In the 6^{th} semester the quantum theory has 3 auditorium hours per week (see the column 20) whereas in the 7^{th} semester the number of auditorium hours per week is 5 (column 21). The number of auditorium hours both in the 6^{th} and 7^{th} semesters is 144 (column 8). This number can also be calculated as 3x18+5x18=144. Eighteen here is the number of weeks for theoretical education in 6^{th} and 7^{th} semesters. This number is shown in the upper part of the columns 20 and 21 and also in the part 1 of the curriculum. We may say also, that number of lecture hours per week on quantum theory is 2 in the 6^{th} semester and 3 in the 7^{th} semester, which gives 2x18+3x18=90 which number is given in the column 9.

The total number of auditorium hours which any individual student can have per week is shown in the lower part of the CP in the line called "Total": 36 in the 1st - 6th semesters, 27 in the 7th semester, 34 and 25 in the 8th and 9th semesters correspondingly. This number never exceeds 36.

One can learn from the curriculum plan, that the specialization disciplines start at 5th semester. All disciplines in the 9th semester are the specialization disciplines.

The curriculum shown in the appendix 4 still is not a complete one. The disciplines of the national&regional section and elective courses are not shown there as well as the local disciplines of specialization (DSL). It follows from CP that the DSL section here consists of 12 disciplines, four of which have exams in the 5, 6 and 9th semesters (see column 3) and tests in 6, 7, 8 and 9th semesters (column 4). The list of these disciplines should be given in a separate sheet similar to that shown in the Appendix 4. The concept of the credit hours does not exist in the present Russian education system.

Master programs

Master programs are parts of ED-system. Everyone having a bachelor diploma can enter the magistracy by competitive examinations and obtain a master degree within the period of two years (104 weeks). As it was pointed out above bachelors do not have specialization. The specialization in the ED-system appears in the magistracy. The complete list of master specializations (master programs) are available through the internet [15]. Some of them are: 510403-"Physics of condensed matter"; 510408-"Physics of atmosphere and near-Earth cosmic space"; 510409-"Astrophysics. Physics of cosmic rays". All these master specializations belong to the ED 510400-"Physics".

The master State Educational Standard provides the following disciplines, which are the same for all physics master programs: the modern problems of physics; the history and methodology of physics; the philosophical problems of natural sciences; the professionally oriented foreign language; computer technologies in education and science; the national and regional component and elective courses. These disciplines form a federal component of the master program and take 1100 hours. The special disciplines take 800 hours and are not defined by the Standard. Each university forms the set of these disciplines according to its scientific schools and traditions, but in agreement with the chosen master program. The theoretical education, therefore, takes 1900 hours and continues for 41 weeks. Examination sessions and holidays take 7 and 12 weeks correspondingly; the scientific and pedagogic practice take 15 and 5 weeks correspondingly; working on the graduate thesis (dissertation) takes 20 weeks and vacation takes 4 weeks. It is evident, therefore, that scientific research is important and large part of the master education program.

The final graduate certification consists of state examination and defending the graduate thesis.

Additional qualification

The programs of high SU-education considered in the previous chapter provide the basic qualification (see the last column in Appendix 1). The students can get the so called additional qualification, which is not obligatory. As is follows from the CP shown in the Appendix 4, the week's number of auditorium hours in the 7-9th semesters is less than 36, therefore there is possibility to fill the curriculum by some additional educational program, parallel with the basic one, shown in Appendix 4. The most popular additional education program gives an additional qualification called "The teacher". A student who graduates with such qualification receives an additional diploma, which permits to work as a teacher of physics. Some other additional qualifications are possible: "The translator of the scientific and technical literature", "The physicist-criminalist", etc.

The total amount of hours for additional qualification is equal to 1400. For teachers the corresponding curriculum includes the following disciplines: psychology and pedagogics (this is the same as GSEF.07 in Appendix 2); age related pedagogical psychology; the theory of education and bringing up; new informational technologies in education; special disciplines. The set of special disciplines depends on the basic qualification. For physicists the special disciplines are following: the history and methodology of physics; the principles of physics teaching; scientific basis of school physics teaching; school physics laboratories and one or two elective courses. Usually the additional qualification starts at 5^{th} -7^{th} semesters. In some universities the additional education it is not free of charge.

The additional education in the ED-system can be obtained only in the magistracy within the limit of 1080 hours above the basic educational program. The most popular additional program for masters is "The high education teacher".

Educational Standards of 3-d generation

The new generation of State Standards of Physics High Professional Education of Russian Federation has recently been approved by the EMC-physics [14]. The basic idea of the 3-d generation Standards is the integration of the Russian education system with that of European Community. Requirements for an obligatory minimum of the contents of the given education programs are not included into the 3-d generation Standards. Instead, these Standards are based on the competences. The basic features of the new Standard, however, are in principal the same as those outlined above. The concept of specialist will not exist any more, so there will remain only two high-educational levels: bachelors and masters. Instead of the “auditorium hours” the “credit hours” will be in use.

The projects of the Standards of 3-d generation have been criticizes by some human rights organizations and leaders of some national republics of Russian Federation [16] because of the absence of the regional component in education. From their point of view the new Standard is not in line with global standards of education, which should provide preserving the national culture of any ethnic group in Russian Federation.

Conclusion

Professor E. De Wolf impartially pointed out that "Russian physics was not different from Western physics. Their poor realizations were due to lack of competition, and that caused the collapse of their system" [17]. The Russian education system as a whole is now at the cross-roads. What is the correct way? Many university professors, scientists and education specialists are very distrustful to the changes towards the European and American systems. Isn't it better to keep the well organized Soviet system?

As it has been mentioned above, tuition in RF is free of charge. Nowadays, however, the parallel system of commercial education also exists. The same university (or institute) can provide both, charge free education and commercial education, but the number of commercial students should not exceed 25 percent of the total student contingent. Usually physics departments have only few commercial students, in contrast with the departments of medicine, economics or jurisprudence.

The charge free education creates many problems. The salary of the university teachers is very modest and is much lower than that of the Soviet period. The average quality of education has been fallen down, although a number of elite universities exist with very high educational level. Government can cover only about 50 percent of the real needs of the universities. It is not declared officially, but in some sense the charge free education is the price the federal government pay for the general stability in the country. Under the bad economical conditions, the charge free high education keeps 3 million young people out from the streets. Due to the internal and external "leakage of brains" the number of scientists in RF has been reduced for the

last 12 years by a factor of 4-5 and amounts today to about 600-700 thousands [18]. It has been pointed out by many authors, that the only way to preserve the high level of physics education is to keep it's fundamental basis [2] (see also [19]). Taking into account all the negative social and economical factors accompanying the physics education in RF, one may conclude, that education is still functioning properly due to the well constructed system, which permits one to overcome these negative factors.

Some negative trends in physics education are international. Professor Martin Huber, the President-Elect of the European Physical Society, has recently pointed out, that "In some European countries the number of physics students has reached dangerously low level; there, physics students aren't even numerous enough to replace today's physics teachers when they retire", and, therefore, the future of our discipline is in jeopardy [20]. To avoid such the negative trends some regions of RF are working out their regional educational programs. Kabardino-Balkarian republic of RF has created the regional "Concept of physics education in general schools", which is, of course, in agreement with federal standards [21]. The concept has been in process since 1996 and today its positive role is evident.

The last decade has created new serious problems in the Russian education system. Formally the Russian officials declare the successful process in the way towards integration with European educational system (in RF this is called “The Bologna Process”). In reality, however, negative undemocratic processes in the society have brought about reinforcement authoritarian trends in the education system both – at the Federal level and in the particular Educational Institutions. As a result the corruption in education has achieved critical level. The role of advanced scientists in the education process has become very modest, whereas all the important decisions concerning the education process are taken by bureaucrats. The hidden motivations of many of such decisions are criminal redistribution of funds. One may very often face a situation when the advanced scientists with world-known publications have no grants, whereas those who are not known by scientific community receive huge amount of funds coming mainly from Russian Ministry of Education and Science. Corruption in this sphere is functioning by means of the so-called “otkats” (“rolling back”). I.e. the funds are in the hand of some bureaucratic groups supporting only those who provide up to 25 % of the grant amount back to them. The Russian Fund of Basic Research is much less corrupt, but the funds provided by it are very modest. Since 2002 the role of the computer testing in the university physics education has been discussed at the annual meetings of Physics Educational and Methodical Council (EMC). I have also participated in such discussions. The general opinion of the university physics community is that the computer testing can be a part of the education process, but it can not be the main instrument testing the quality of the physics education. How can the computer testing value the knowledge in theoretical physics, for example? In October 2003 the director of the Testing Center of Professional Education Mr. Vasiliev V.I. [22] has been invited to the meeting of the university physics community, where about 50 deans of physics departments of Russian universities participated [23]. Having no reasonable arguments Mr. Vasiliev simply said “Federal computer testing will be a reality independently on your decisions”. This is a typical way of solving of most of the educational problems in modern Russian Federation. Such situation is in evident contradictions with the European university declarations.

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Table 1

Physics for 7th grade pupils of the general school (12-13 years old) [7]

No	The section	Basic formulas, details	Amount
I	II	III	IV
1	Introduction	What the physics is?	6 %
1	The primary information about the structure of substance	Atoms and molecules; solids; liquids; gases	9 %
2	Interaction between the bodies	The motion; trajectory; $v = s/t$; average velocity; density $\rho = m/V$; the weight $P = mg$, g=9.8 N/kg	20 %
3	The pressure of the solid bodies, liquids and gases	The pressure $p = F/S$; pressure in the liquids $p = \rho gh$; an Archimedes law	24 %
4	The work and the power. Energy.	The work $A = F \cdot s$; the power $N = A/t$; the force momentum $M = F \cdot l$; the potential energy $E = mgh$	15 %
5	Appendixes	1. Laboratories 2. Additional reading 3. Additional problems	26 %

Table 2

Physics for 8th grade pupils of the general school (13-14 years old) [8]

No	The section	Basic formulas, details	Amount
I	II	III	IV
1	Thermal phenomena	Heating of a body $Q = cm(t_2 - t_1)$, c is the thermal capacity;	14 %
2	The change of different states of matter	Melting, boiling, burning and corresponding amounts of heat	12 %
3	Electrical phenomena	Charges; electrical current I=q/t; the voltage U=A/q, A is a work, q is a charge; resistance R; Ohm's law I=U/R; the resistance of the wire $R = \rho l/S$, ρ is the specific resistance; the work of the current A=UIt; electrical circuit and its resistance; the heat in the electrical circuit $Q = I^2Rt$	35 %
4	Electromagnetic phenomena	Magnetic field; magnetic interaction of the currents	8 %
5	Light phenomena	Propagation of light; reflection and refraction; lenses	18 %
6	Appendixes	1. Laboratories 2. Additional reading 3. Additional problems	13 %

Table 3

Physics for 9th grade pupils of the general school (14-15 years old) [9]

No	The section	Basic formulas, details	Amount
I	II	III	IV
		Kinematics	
1	General views on motion	Vectors; the systems of coordinates; $\mathbf{s} = \mathbf{v}\,t$	14 %
2	The straight line non-uniform motion	Acceleration $\mathbf{a} = (\mathbf{v} - \mathbf{v_0})/t$; $s = v_0 t + at^2/2$; $v^2 = v_0^2 + 2as$	7 %
3	The circular motion	Centripetal acceleration $a = v^2/r$; the period of rotation T; $v = 2\pi r/T$	5 %
		Dynamics	
4	The laws of motion	Newton laws; $\mathbf{a} = \mathbf{F}/m$;	12 %
5	The forces in nature and the motion of bodies	The force of elasticity $F = -kx$; Newton's gravitation law $F = Gm_1m_2/R^2$; motion in the constant gravitational field	19 %
		Conservation laws in mechanics	
6	The momentum conservation	$\mathbf{F}\,t = m\mathbf{v} - m\mathbf{v_0}$; $m_1\mathbf{v}_1 + m_2\mathbf{v}_2 = m_1\mathbf{v}_1' + m_2\mathbf{v}_2'$	7 %
7	The energy conservation	The work $A = Fs\cos\alpha$; kinetic energy $mv^2/2$; potential energy mgh; elastic energy $kx^2/2$; power N=A/t; N=Fv; efficiency $\eta = A/A_0$	15 %
		Oscillations and waves	
8	Mechanical oscillations	Frequency $\nu = 1/T$; oscillation energy; $x = A\sin(2\pi t/T)$; period $T = 2\pi\sqrt{m/k}$; $T = 2\pi\sqrt{l/g}$; resonance;	8 %
9	The waves	Wave length $\lambda = vT$; transverse and longitudinal waves; the sound;	7 %
10	Appendix	Laboratories	5 %

Table 4

Physics for 10th grade pupils of the general school (15-16 years old) [10]

No	The section	Basic formulas, details	Amount
I	II	III	IV
Molecular physics. Thermal phenomena.			
1	The kinetic molecular theory	Avogadro number N_A; the number of molecules $N = N_A m/M$; pressure of the ideal gas $p = 2nE/3$	9 %
2	Temperature. The thermal energy of molecules.	Absolute temperature; state equation for ideal gas (IG) $pV = NkT$; $E = 3kT/2$; $p = nkT$;	5 %
3	The state equation of ideal gas (IG)	$pV = (m/M)RT$; pV=const when T=const;	4 %
4	The mutual transformations of liquids and gases	Evaporation and condensation; boiling; absolute and relative humidity; the saturated vapor;	5 %
5	The solid bodies	Crystals; amorphous media; a Hooke's law $\sigma = E\lvert\varepsilon\rvert$; σ is the tension, ε is a relative lengthening,	5 %
6	The principles of thermodynamics	Internal energy of IG $U = (3/2)mRT/M$; the work $A = -p\Delta V$; $Q = cm\Delta t$; melting heat $Q = \lambda m$; the first law of thermodynamics $Q = \Delta U + A$; $\eta = (T_1 - T_2)/T_1$	12 %
Electrodynamics			
7	Electrostatics	Coulomb law $F = kq_1q_2/r^2$; $k = 1/(4\pi\varepsilon_0)$; $\mathbf{E} = \mathbf{F}/q$; $\mathbf{E} = \mathbf{E_1} + \mathbf{E_2} + \ldots$; $U = \varphi_1 - \varphi_2 = A/q$; the capacitance $C = q/U$; electrostatic energy density in the condenser $w = \varepsilon\varepsilon_0 E^2/2$;	19 %
8	The laws of constant current	$I = \Delta q/\Delta t$; Ohm's law I=U/R; resistance of the wire $R = \rho l/S$, ρ is the specific resistance ; parallel and consecutive connection of resistances; Joule's heat Q=IUt; Ohm's law for closed circuit $I = \mathcal{E}/(R+r)$, R and r are the external and internal resistances;	8 %
9	The magnetic field	Ampere's force $F = BI\Delta l\sin\alpha$; Lorentz's force $F = qvB\sin\alpha$; $\mathbf{B} = \mu\mathbf{B_0}$;	8 %
10	The electrical current in the different substances	Temperature dependence of resistance; semiconductors; diodes and transistors; Faraday's laws of electrolysis $m = kI\Delta t$;	16 %
11	Appendixes	Laboratories	9 %

Table 5

Physics for 11th grade pupils of the general school (16-17 years old) [11]

No	The section	Formulas	Amount
I	II	III	IV
Electrodynamics (continuation)			
1	Electromagnetic induction	Magnetic flux $\Phi = BS\cos\alpha$; the law of electromagnetic induction $E = -\Delta\Phi/\Delta t$; selfinduction $\Phi = LI$; magnetic field energy of the current $W = LI^2/2$;	9 %
Oscillations and waves			
2	Electromagnetic oscillations	Oscillating contour; angular frequency $\omega = 2\pi/T$; period of electrical oscillations in the contour $T = 2\pi\sqrt{LC}$;	12 %
3	The production, transformation and use of the electric energy	Transformers; $U_1/U_2 = N_1/N_2$, N_i is the number of turns in the transformer;	4 %
4	Electromagnetic waves	The density of the electromagnetic radiation flux $I = \Delta I/(S\Delta t)$; $I \quad E^2 + B^2$; radio; radio receiver;	11 %
Optics			
5	The light waves	Laws of geometrical optics; $\sin\alpha/\sin\beta = n_1/n_2$; dispersion of light; interference and diffraction $\Delta d = k\lambda$; polarization;	16 %
6	The elements of special relativity	$l = l_0\sqrt{1 - v^2/c^2}$; $\tau = \tau_0/\sqrt{1 - v^2/c^2}$; $m = m_0/\sqrt{1 - v^2/c^2}$; $\mathbf{p} = m_0\mathbf{v}/\sqrt{1 - v^2/c^2}$; $v_2 = (v_1 + v)/(1+v_1v/c^2)$; $E=mc^2$;	5 %
7	Radiation and spectra	Types of spectra; infrared and ultraviolet radiation; spectroscopy; X-rays;	6 %
Quantum physics			
8	The light quanta	$E=h\nu$; photoeffect $h\nu=A+mv^2/2$; photon momentum $p=h\nu/c$;	5 %
9	Atomic physics	Rutherford's atom; Bohr's postulates; $h\nu_{kn} = E_k - E_n$; lasers;	5 %
10	Physics of atomic nuclear	Detectors; α, β and γ radiation; ${}^{M}_{Z}X \rightarrow {}^{M-4}_{Z-2}Y + {}^{4}_{2}He$; ${}^{M}_{Z}X \rightarrow {}^{M}_{Z+1}Y + {}^{0}_{-1}e$; neutrons; nuclear reactions; defect of mass; nuclear reactors; nuclear weapons; biological action of radiation;	15 %
11	Elementary particles	Electrons; protons; anti matter; quarks;	5 %
12	Laboratories	Laboratories	7 %

Appendix 1

Physical specialities with some specializations
(the number of specializations is shown in the brackets)

No	Code number	Specialities and some corresponding specializations	Qualification
1	**010400**	**Physics (57)**	**Physicist**
	010401	Theoretical physics	
	010409	Solid state physics	
	010407	Plasma physics	
	010427	Geophysics	
	010431	Computer methods in physics	
	010433	Medical physicas	
	010445	Mathematical physics	
	010446	Applied physics	
2	**010600**	**Physics of Condensed Matter (15)**	**Physicist**
	010601	Physics of crystals	
	010614	Physics of polymers	
	010615	Physics of non-liner dynamical systems	
3	**010700**	**Physics of atomic nuclear and particles (18)**	**Physicist**
	010701	Physics of atomic nuclear and nuclear reactions	
	010706	Plasma physics	
	010707	Physics of nuclear reactors	
4	**010800**	**Physics of kinetic phenomena (4)**	**Physicist**
	010802	Kinetic phenomena in condensed media	
	010803	Physics of explosions	
5	**010900**	**Astronomy (5)**	**Astronomer**
	010901	Astrophysics	
	010903	Radio astronomy	
6	**013800**	**Radiophysics and electronics (26)**	**Padio-physicist**
7	**013900**	**Fundamental radiophysics and physical electronics (19)**	**Physicist**
8	**014000**	**Medical physics (7)**	**Physicist**
	014001	Nuclear medicine	
	014005	Tomography and X-ray visualisation	
9	**014200**	**Bio-chemical physics (6)**	**Physicist**
10	**014300**	**Physics of Earth and planets (6)**	**Physicist**

Appendix 2 (part 1)

Requirements to an Obligatory Minimum of Contents of the Education Program on a Speciality 010400-"Physics"

Index	The names of the disciplines	The total amount of hours
GSE	**General humanitarian and social-economic disciplines**	**1800**
GSEF	Federal component	1260
GSEF.01	Foreign language	340
GSEF.02	Physical culture (sport)	408
GSEF.03	The state history (the history of Russian Federation)	
GSEF.04	Cultural science	
GSEF.05	Political science	
GSEF.06	Jurisprudence	
GSEF.07	Psychology and pedagogics	
GSEF.08	Russian language and the culture of speech	
GSEF.09	Social science	
GSEF.10	Philosophy	
GSEF.11	Economics	
GSER	National and regional component	270
GSEC	The choice	270
NS	**General mathematical and natural science disciplines**	**3440**
NSF	Federal component	3140
NSF.01	General physics	
NSF.01.1	Mechanics	
NSF.01.2	Molecular physics	
NSF.01.3	Electricity and magnetism	
NSF.01.4	Optics	
NSF.01.5	Physics of atoms and atomic phenomena	
NSF.01.6	Physics of atomic nuclear and particles	
NSF.02	General physics laboratories	650
NSF.03	Mathematics	1150
NSF.03.1	Mathematical analysis	
NSF.03.2	Analytical geometry	
NSF.03.3	Linear algebra	
NSF.03.4	Vector and tensor analysis	
NSF.03.5	The functions of complex variables	
NSF.03.6	Differential equations	
NSF.03.7	Integral equations and variational methods	
NSF.03.8	The probability theory and statistics	
NSF.04	Informatics (computer science)	
NSF.04.01	Programming	
NSF.04.02	Computational physics (computer labs)	
NSF.04.03	Numerical methods	
NSF.05	Chemistry	70
NSF.06	Ecology	70

Appendix 2 (part 2)

Index	The names of the disciplines	The total amount of hours
NSFR	National and regional component	150
NSFC	The choice	150
GPD	**General professional disciplines**	**1310**
GPDF	Federal component	1110
GPDF.01	Theoretical physics	870
GPDF.01.1	Mechanics	
GPDF.01.2	Mechanics of continuous media	
GPDF.01.3	Electrodynamics	
GPDF.01.4	Electrodynamics of continuous media	
GPDF.01.5	Quantum theory	
GPDF.01.6	Physics of condensed state	
GPDF.01.7	Thermodynamics	
GPDF.01.8	Statistical physics	
GPDF.01.9	Physical kinetics	
GPDF.02	Methods of mathematical physics	240
GPDF.02.1	Linear and non-linear equations of physics	
GPDR	National and regional component	100
GPDC	The choice	100
DS	**Disciplines of specialization**	**1532**
DS.01	Geophysics	
DS.02	Radiophysics and electronics	
DS.03	Biophysics	
DS.04	Physics of condensed state	
DS.05	Astrophysics	
DS.06	Physics of fundamental interactions	
DS.07	Special laboratories	
DS.08	The undergraduate's thesis	
DSL	Local disciplines of specialization	
OC	**Optional courses**	**450**
OC.01	Military	450
	Total amount of theoretical education	**8532**
	Practice	648
	Total	**9180**

Appendix 3

The time allowed for different types of educational activity.
Speciality 010400-"Physics"

No	The type of activity	Duration in weeks
1	Theoretical classes, which consist of lectures, practical classes and laboratories;	158
2	Sessions, which define the period of examinations (twice a year)	28
3	Practices, i.e. the time spent in the scientific laboratories, factories, industrial laboratories, general schools etc.	12
4	Preparation and defending the graduate thesis	20
5	Holidays including the final vacation	42
	Total	**260**

CURRICULUM
SPECIALITY "010400 - Physics"

Qualification - "Physicist"
Duration of education: 5 years

1. The schedule of the educational process

YEARS	SEPTEMBER				OCTOBER					NOVEMBER				DECEMBER				JANUARY				FEBRUARY				MARCH					APRIL				MAY					JUNE					JULY				AUGUST					summary (number of weeks)									
	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	4	11	18	25	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	2	9	16	23	30	Theor.ed.	Sessions	Teach.practice	Prof. practice	Edcat. pract.	Graduate work	State exam.	Holidays	Vacation	TOTAL
1																		E	E	E	E	-	-																	E	E	E	E	-	-	-	-	-													
2																		E	E	E	E	-	-																	E	E	E	E	-	-	-	-	-													
3																		E	E	E	E	-	-																	E	E	E	E	-	-	-	-	-													
4																		E	E	E	E	-	-																	E	E	E	E	-	-	-	-	-													
5														E	E	-	-	x	x	x	x	x	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	F	F	o	o	o	o	o	o	o													
6																																																																							

NOTATIONS : [ ] - Theoretical education; [E] - Exam sessions; [H] - Teaching practice; [x] - Professional practice; [S] - Scientific practice
[-] - Holidays; [o] - Vacation; [F] - Final State examinations; [T] - Preparation of the graduate thesis

2. Curriculum plan

Nos	DISCIPLINES	Distribution over semesters			NUMBER OF HOURS									Distribution over semesters									
					According to the Standard	including								1 year		2 year		3 year		4 year		5 year	
						Total hours	including					u/thesis	Self-training	1	2	3	4	5	6	7	8	9	10
		Examinations	Tests	Undergraduate's thesis (u/thesis)			Auditorium hours	Lectures	Laboratories	Practical classes	Seminars			Number of week in semester									
														18	18	18	18	18	18	18	18	14	
														Number of hours per week									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
GSE	General humanitarian and social-economic disciplines				1800	1800	1038	242		634	162		762	11	13	10	12	2	2	2	6		
GSE.00	*Federal component*				1260	1260	768	134		562	72		492	9	8	6	8	2	2	2	6		
01	Foreign language	24	13		340	340	180			180			160	2	4	2	2						
02	Physical culture (sport)		2468		408	408	408	26		382				4	4	4	3	2	2	2	2		
03	The state history (the history of Russian Federation)	1				176	54	36			18		122	3									
07	Psychology and pedagogics		4			160	54	36			18		106				3						
10	Philosophy	8				176	72	36			36		104								4		
GSER	*National and regional component*	2	2		270	270	126	36		72	18		144	2	5								
GSEC	*The choice (elective courses)*		3344		270	270	144	72			72		126			4	4						
NS	General mathematical and natural science disciplines				3440	3440	1962	846	522	594			1478	25	23	22	14	13	12				
NSF	*Federal component*				3140	3140	1818	774	522	522			1322	23	21	22	14	9	12				
NSF.01	General physics				1000	1000	540	324		216			460	6	6	5	5	5	5				
01.1	Mechanics	1				160	90	54		36			70	5									
01.2	Molecular physics	2				180	90	54		36			90		5								
01.3	Electricity and magnetism	3				160	90	54		36			70			5							
01.4	Optics	4				180	90	54		36			90				5						
01.5	Physics of atoms and atomic phenomena	5				160	90	54		36			70					5					
01.6	Physics of atomic nuclear and particles	6				160	90	54		36			70						5				
NSF.02	General physics laboratories		123 456		650	650	432		432				218	4	4	4	4	4	4				
NSF.03	Mathematics:				1150	1150	630	360		270			520	9	8	13	5						
03.1	Mathematical analysis	123				480	288	144		144			192	6	6	4							
03.2	Analytical geometry	1				100	54	36		18			46	3									
03.3	Linear algebra	2				60	36	18		18			24		2								
03.4	Vector and tensor analysis		3			70	54	36		18			16			3							
03.5	The functions of complex variables	3				140	54	36		18			86			3							
03.6	Differential equations	3				130	54	36		18			76			3							
03.7	Integral equations and variational methods	4				70	36	18		18			34				2						
03.8	The probability theory and statistics	4				100	54	36		18			46				3						
NSF.04	Informatics (computer science)				200	200	144	54	90				56	3	2			3					
04.1	Programming		1			60	54	18	36				6	3									
04.2	Computational physics (computer labs)		6			80	54	18	36				26					3					
04.3	Numerical methods		2			60	36	18	18				24		2								
NSF.05	Chemistry		2		70	70	36	18		18			34		2								
NSF.06	Ecology		1		70	70	36	18		18			34	2									
NSFR.00	*National and regional component*		5		150	150	72	36		36			78				4						
NSFC.00	*The choice (elective courses)*		12		180	150	72	36		36			78	2	2								
GPD	General professional disciplines				1310	1310	774	414		360			536			4	4	10	7	10	8		
GPDF.00	*Federal component*				1110	1110	702	378		324			408			4	2	10	7	10	6		
GPDF.01	Theoretical physics				870	870	594	324		270			276			4	2	4	7	10	6		
01.1	Mechanics	3				130	72	36		36			58			4							
01.2	Mechanics of continuous media		4			60	36	18		18			24				2						
01.3	Electrodynamics	5				100	72	36		36			28					4					
01.4	Electrodynamics of continuous media	6				100	72	36		36			28						4				
01.5	Quantum theory	7	6			200	144	90		54			56						3	5			
01.6	Physics of condensed state		8			60	36	18		18			24								2		
01.7	Thermodynamics and statistical physics	7				120	90	54		36			30							5			
01.8	Physical kinetics	8				100	72	36		36			28								4		
GPDF.02	Methods of mathematical physics				240	240	108	54		54			132					6					
02.01	Linear and non-linear equations of physics	5			240	240	108	54		54			132					6					
GPDR.00	*National and regional component*	4			100	100	36	18		18			64				2						
GPDC.00	*The choice (elective courses)*		8		100	100	36	18		18			64								2		
DS	Disciplines of specialization				1532	1532	1106	496	414	196		24	402					5	9	9	19	25	
01	Geophysics		7	7		80	36	18		18		3	41							2			
02	Radiophysics and electronics	6	5			150	126	36	54	36			24					3	4				
04	Physics of condensed state	8				90	72	54		18			18								4		
05	Astrophysics	7				115	54	36		18			61							3			
06	Physics of fundamental interactions	8				115	72	36		36			43								4		
07	Special laboratories		789			175	146		146			3	26							2	3	4	
08	The undergraduate's thesis			789																			
DSL.00	Local disciplines of specialization	5699	6758 9999	9		807	600	316	214	70		18	189					2	5	2	8	21	
OC	Optional courses				450	450	450	144		276	30							6	6	6	6	1	
OC.01	Military	57	468		450	450	450	144		276	30							6	6	6	6	1	
IV. Some other optional courses				TOTAL	8532	8532	5330	2142	936	2060	192	24	3178	36	36	36	36	36	36	27	34	25	

The name of the course	term	hours
1. Computer systems	3	108
2. Foreign language	4	126
3. Sport	5	208

NUMBER OF UNDERGRADUATE'S THESISES	5
NUMBER OF EXAMINATIONS	38
NUMBER OF TESTS	47

V. Teaching practice	VI. Professional practice
The name of the practice	The name of the practice
Research practice	Professional practice

VII. Final State examinations	
1.	State examination on the speciality