A review of high-level Russian physics education

university level

The system of science higher education in Russia has a unique history. The system is different from those in other countries in Europe, and from the system in the US, where both research and education are concentrated at universities. Traditionally in Russia, the two activities were separate. Universities took care of education, while scientific research was done mainly by institutions of the Russian Academy of Sciences (RAS)—nowadays, many university professors are involved in research and many researchers give lectures at universities, but the basic idea of universities (to educate) and RAS institutions (to conduct research) remains the same.

The system was good many years ago in preparing engineers for work in industry with traditional technologies. But it became ineffective in the epoch of atomic bombs and advanced technologies. Hence, within this system an elite section was created where students would get a basic, more or less common, education during 3 years and then spend 3 years at research centres listening to lecture courses given by researchers and, in parallel, participating in frontier research themselves. This system was first tried in the 1950s at the Moscow Institute of Physics and Technology (MIPhT) which began sending its students to a hundred different research institutions. Later, the same system was used in Novosibirsk and other scientific centres. All sides benefit from such cooperation. University professors get access to modern equipment, the research centres obtain an influx of young specialists, and the brightest students can follow a straight path into fundamental physics research.

The system has some variants. For instance, the Advanced Physics Faculty (APF), an elite subdivision of the Moscow Engineering Physics Institute (MEPhI), was founded under the Soviets in 1991 (the dissolution of the Soviet Union was in December 1991). It accepts students who have completed their first year (of their three years in an RAS institute) at MEPhI and demonstrated outstanding abilities. In addition to physics they are expected to have strong skills in computer programming and to be able to speak two or three foreign languages fluently.

The system is evolving, too. A branch of the Moscow State University (MSU) is being set up within Chernogolovka, a well-known Russian centre of scientific research in the Moscow region. It already has departments of physics and astronomy, chemistry, and geology with a small number (5 to 10) of undergrad students and graduate students each. Departments of biology and mathematics will be added soon.

Unfortunately, provincial universities are not capable of establishing close cooperation with other academic institutions outside their region because of the farness and poorly developed telecommunications network in Russia. For graduates of such universities there is generally no possibility for continuing education outside the local region. To compensate for this, at least partly, the Special Physics Faculty (SPF) of MEPhI was founded jointly with the Lebedev Institute of Physics of the RAS back in 1971. Here, students are selected after the first two to three years of their education at regional universities, and move to the SPF in Moscow to study for at least three years. Over 740 students have already come through the system of SPF. The main objective of this project is to prepare scientists for regional education and research institutions scattered over the large territories of Russia (Siberia, Far East, Urals). According to an agreement, after graduation from SPF, the students must return to their *alma mater* university and get an assignment from and a position in that university. Alumni of SPF, in fact, have become the core of many leading research groups in different remote regions of Russia, such as Vladivostok, Samara, *etc.*

Another important issue of the science education system in Russia is the recruitment of high-school graduates to universities. Physics and mathematics, like music, ballet, sports and foreign languages, need years of hard study from an early age in order to be mastered at an appropriate level. It is crucial to start training future scientists well before university. Understanding that, many universities have organized schools and lyceums with advanced programs in physics and mathematics. Thus, Novosibirsk State University has a boarding school for gifted children. MEPhI has two lyceums in which pupils study for the last two years before entering the institute. Moscow Institute of Physics and Technology (MIPhT) and MSU have close connections with certain schools, too, accepting more students from these schools than from others.

The system, as described above, operated perfectly during Soviet times when science and education received abundant funding from the government. During those times there was a lot of competition in gaining entry to universities. The job of researcher was prestigious and highly paid. And academic institutes could choose the best among the numerous graduates of universities.

At present, while there is a huge economic crisis in Russia, science and education are extremely underfunded. Universities are not able to renew out-of-date equipment, and faculties have dropped to half their size. Academic institutes struggle for survival while the average age of researchers has risen to fifty years. As for the young generation of physicists, a growing percentage of students and postgraduates continue education and research abroad. Many of them stay there for a long time, sometimes forever. For instance, as much as 80% of those who graduated from MIPhT in 1995 with a specialization in solid state physics are now working at scientific institutions in Europe and the US. Some of them have already received their PhD abroad.

Thus, the system of science in Russia faces very serious problems of allocation and employment. The standards of physics education in Russia, once high, are yet kept high, but it becomes more and more dif-

	comprehensive school		
AGE	6 years	10 years	14 years

ficult to keep the pace and maintain the level.

Nonetheless, there are positive aspects which inspire optimism and the hope of better things. A small but stable tendency has been reported in recent years: the competition to gain entry to physics departments at universities is getting harder. The need for higher education in getting a good job has influenced the minds of young people. At the same time, new leaders have been elected at universities—Victor Sadovnichii at the MSU, Nikolay Kudryavtsev at the MIPhT, Boris Onykii at MEPhI. They feel and understand the new situation.

By definition, students and postgraduates are young and energetic, they are more mobile and have fewer needs than 'ripe' scholars. Provided the relatively small funding, they can implement labour-intensive work with high productivity, thus yielding a maximum payoff. Several major international companies such as Microsoft, Intel, Samsung, *etc*, have acknowledged that and begun cooperating with a number of Russian universities by giving stipends to students who become their employees afterwards.

But more important for Russian universities are the contacts with Western universities and physical communities. Some joint projects are already underway. For instance, a grant exists, under the Leonhard Euler Programme in Germany. It provides a monthly stipend of 150 Deutsch marks to 20 undergraduate students of three Moscow universities who are taking advanced courses at the Institute of Solid State Physics of the RAS. The only condition for these students is that they learn German. Some of them, 5 of the 20, took the opportunity to pay a short visit to Germany last year.

The example above represents indirect cooperation between foreign institutions and the Russian education network through the RAS. But the leading Russian universities themselves are looking for direct contacts and direct cooperation with foreign institutions. One of the most promising types of such cooperation would be financial support from the West to a Russian university with a condition that the university sends its graduates of a certain specialization to postgraduate and/or postdoc positions in the West. Programs of student exchange are also very useful. They allow the training of specialists at an international level and furthermore facilitate the integration of Russian science and Western science.

Despite the problems, physics education remains one of the few fields where Russia competes successfully with Europe and America. It is perhaps surprising given our recent history, but the intellectual potential of Russia has not been diminished. There is still an influx of bright young people who, given a good education, promise to become scientists of the highest grade. By financing joint programs the West can invest in the future, and this has all the promise of being profitable to everybody.

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School begins at the age of 6 and lasts 11 years. During the last two years pupils often leave for another school or lyceum to get a better training in a narrower field (like physics and mathematics, or economics, foreign languages, *etc*) and to prepare for university. Usually, there is a competition for entry into such schools, including exams in a major field. And such schools only exist in large towns, which means that youngsters from small towns are handicapped (in Novosibirsk the Internet is being used to compensate for this).

At the age of 17 pupils finish school by passing exams. Normally the exams include 2 to 3 obligatory subjects (like mathematics, or essay writing) and 1 to 2 subjects which are the choice of the pupil (like foreign language, chemistry, history).

Normally, young people enter **university** at the age of 17 right after they have finished school. The entrance exams to universities that teach physics usually include essay writing, physics and mathematics. Each university has its own examination programme which varies in difficulty depending on the level of competition, the rank of the university, *etc*. Graduates of lyceums affiliated with universities often have an advantage because their finishing exams at school are also entrance exams to a certain university.

University education in physics takes 5 to 6 years. After the third year students choose their specialisation and are assigned to a relevant research group. At the end, students are required to defend a diploma. The traditional diploma is called Engineer-Physicist (or *Ingener-Physik* in Russian pronunciation), and is equivalent to a Master's degree. But in the last couple of years many universities have been transferring to the Western system and have introduced a two-stage education system.

The first stage lasts 4 years and leads to the degree of Bachelor (or *Bakalavr-Physik*). The second stage is expected to last 2 years and lead to the Master's degree (*Magistr*). Right now, the transfer to the new education system is underway. So students have an option of receiving the degree of either Engineer-Physicist or Bachelor, or both.

At the age of 22 or 23, after graduating from university, students can pursue **post-graduate** study (in Russia post-graduate study is called *Aspirantura*). To do that, they must pass three exams: the field of physics in which they specialize, philosophy and a foreign language. They must also have been recommended for postgraduate study by a scientific group or department. *Aspirantura* usually lasts 3 to 5 years and leads to the degree of Candidate of Physical and Mathematical sciences (*Kandidat Physiko-Matematicheskih Nauk*), which is equivalent to a PhD.

A higher degree than a PhD exists. The degree is called Doctor of Physical and Mathematical Sciences (*Doktor Physiko-Matematicheskih Nauk*). The degree has no equivalent in the US education system but does have one in Europe—the Habilitation in Germany. Usually, this takes 5 to 10 years but it is not a part of the normal educational process and the terms of study are not specified. In Soviet times this 2nd doctorate led to a salary increase from 250 roubles to 450 roubles.

Russia

Bakalavr-Physik	Magistr	Kandidat	Doktor
18 years	22 years	26 years	