Physics and astronomy at Moscow University[1] (On the University's 225th anniversary)

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Written in observance of the 225th anniversary of Moscow State University, the paper briefly reviews the development of physics, astronomy, and geophysics at the University from its founding to the present day. Both the teaching and the scientific activities of Moscow University scientist-instructors are discussed.

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Moscow University played a special role in the history of Russian science and culture. It was the country's first institution of higher learning and for a long time—to the beginning of the Twentieth Century—it remained Russia's only university. From that day to ours, however, Moscow University has occupied and continues to occupy a leading position among the higher educational institutions of the Soviet Union.

Moscow University was opened in 1755. The principal motive force behind its creation was M. V. Lomonosov, the founder of Russian science and the first Russian academician, whose name the University bears.

THE EARLY PERIOD IN DEVELOPMENT OF PHYSICS AT MOSCOW UNIVERSITY (1755-1866)

This first period in the development of physics at Moscow University began almost with the University's founding and continued until A. G. Stoletov joined the physics department in 1866. During this period, physics at the University consisted basically of instruction, but the results of scientific work were rather modest throughout the entire period.

Lecturing in physics had started at the university as early as 1757. However, until 1791, when the physics chair was occupied by P. I. Strakhov, the level of the lectures was not particularly high. The lecturers were chosen haphazardly and were usually strangers to the actual science.

Strakhov was the first to teach a serious physics course at the University. His first teaching aid was Brisson's French-language textbook, which he translated into Russian, but in 1810 he replaced it with his own "Brief Outline of Physics."

Strakhov did not confine himself to the reading of physics lectures. He also did scientific work, chiefly in the area of geophysics—study of the climate of Moscow—and also occupied himself with investigations of atmospheric electricity and electricity in general. Strakhov began to attract students to scientific work. They worked in a physics study that he had furnished. A surviving paper written jointly with his students was entitled "Galvanic and Electrical Experiments Conducted on the Moscow River" and published in 1806 in the "Zapiski Obshchestva Ispitateleĭ Prirody" (Notes of the Society of Natural Historians), of which Strakhov was one of the organizers.

This paper described experiments in which Strakhov and his students sent an electric current across the Moscow River on wires. Although the scientific results of the effort were modest, it shows that Strakhov was abreast of the latest advances in physical science. After all, it was not until 1800 that the first galvanic element—the voltaic pile—was invented and direct-current experimentation techniques began to develop.

Strakhov's activity at Moscow University continued until 1812, when the approach of Napoleon's armies to Moscow forced partial evacuation of the university. Only the teaching staff and a small amount of equipment were evacuated from the city, and most of the university's property was destroyed when the city was burned.

Reconstruction of the University was begun in 1813. The activity of the physics chair also resumed at that time with I. V. Dvigubskiĭ as its professor, Strakhov having died. Dvigubskiĭ, a Doctor of Medicine, was a scientist of broad vision. Although he was not a specialist in physics, he managed to master the instruction of students in this science. He himself lectured successfully in physics. He translated Jaucoteau's French-language textbook into Russian and later republished it with a whole series of revisions and supplements, producing what was for that time a quite satisfactory university physics text. Dvigubskiĭ gave a great deal of attention to providing students with instruction in experiment. He restored the physics center in a substantially expanded form. Students were also attracted to scientific work under Dvigubskiĭ. As an example, we might cite N. V. Kotsaurov's Master's Thesis "A Discussion of Measurement of Altitude with the Barometer," which was written in 1823.

Dvigubskiĭ also performed a service in organizing the scientific journal "New Magazine of Natural History, Physics, Chemistry, and Economic Information." This journal was published for 10 years starting in 1820. It is interesting to note that at a time when the caloric theory held sway (1826), this journal carried Dvigubskiĭ's Russian translation of Lomonosov's paper "On the Cause

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of Heat and Cold," which was devoted to development of the kinetic theory of heat.

Between Dvigubskiĭ's departure from the physics chair in 1827 and the appearance of Stoletov at Moscow University, note should be taken of the work of D. M. Perevoshchikov. Perevoshchikov was an astronomer and mathematician. He worked at Moscow University from 1818 through 1851. One of his accomplishments was organization of the Moscow University Astronomical Observatory at *Presne* (1831). Perevoshchikov also lectured in physics for a time in the late 1830s.

Professor M. R. Spasskiĭ was head of physics at the University from 1839 through 1859. He introduced the practice of separate instruction in experimental and theoretical physics. Spasskiĭ's scientific work was concerned chiefly with problems of climatology. Spasskiĭ was of definite service to this science, especially through his studies of the climate of Moscow.

In 1859–1882, the teaching of physics at Moscow University was the responsibility of Prof. N. A. Lyubimov. Under his direction, physics was taught at a higher level. In the words of Umov, who attended Lyubimov's lectures, the latter "at once elevated the teaching of physics at Moscow University by talented exposition, popularization of the science, and his effort to raise its teaching to the level with which he had become acquainted on his foreign travels."

Lyubinov devoted much effort to equipping the physics laboratory with instruments and improved its demonstrated experiments considerably. The services of I. F. Usagin, who is credited with a long list of physical-instrumentation inventions, were secured for the laboratory. He was, for example, one of the inventors of the transformer.

Lyubimov's scientific heritage consists mainly of his work in the history of physics. Among his works is the major three-volume "A History of Physics."

PHYSICS AND ASTRONOMY AT MOSCOW UNIVERSITY FROM THE MID-NINETEENTH CENTURY TO THE GREAT OCTOBER SOCIALIST REVOLUTION

A new period in the development of physics at Moscow University began when the physics chair was taken by A. G. Stoletov, who raised the level of physics teaching at Moscow to that of the western European universities. Under Stoletov, scientific work also began to develop on a broad scale at the university, which became the leading Russian scientific institution in the field of physics.

Stoletov was born in 1839. He graduated from the physicomathematical department of Moscow University in 1860 and was persuaded by Lyubimov to remain there to work for a professorship. Stoletov was soon sent abroad to work in Germany, part of the time under Kirchhoff at Heidelberg. After his return to Moscow, Stoletov first began to teach a course in mathematical physics, and after 1882, when Lyubimov left the university, a course in experimental physics, which he continued until his death in 1896.

From the very beginning of his career at the university, Stoletov recognized clearly that an experimental base would be necessary to raise the level of physics teaching and to expand serious scientific work at the university. He therefore made it his task to organize both teaching and scientific laboratories at the university and was eventually able to put across his ideas.

However, none of the prerequisites for experimental work was present immediately after Stoletov's return from abroad. He therefore undertook a theoretical study. His first paper was devoted to the distribution of electricity on conductors in the presence of predetermined electric charges.

His second scientific paper, however, was experimental. Even while abroad, he had become interested in the relation between induction and magnetic field intensity in the presence of ferromagnetics. This problem had not yet been seriously investigated, although it was becoming more important with each passing year in connection with the development of electrical engineering, in which the use of iron-core electromagnets was increasing steadily.

However, it was impossible to carry out this investigation at Moscow: there was as yet no real scientific laboratory. In 1871, Stoletov went to Kirchhoff's laboratory at Heidelberg to make the required measurements. Returning to Moscow and reducing his results, he wrote a paper entitled "An investigation of the Magnetization Function of Soft Iron," which he defended as a doctorate dissertation in 1872.

In this paper, Stoletov determined how magnetic susceptibility depends on magnetic field intensity for soft iron. He established that susceptibility first increases with increasing magnetic field strength, reaches a maximum, and then decreases slowly. The value of this study goes beyond the result obtained: to carry it out, Stoletov developed an experimental method that was subsequently widely used in magnetic measurements.

In 1872, the building in the university courtyard that had served as the rector's quarters became available. Some of the space in this building was set aside for a physics laboratory. Here Stoletov set up a physical practicum and a physics laboratory.

In 1888, Stoletov investigated the photoeffect that had recently been discovered by Hertz. He established a whole series of relationships in the photoeffect. He showed that the photoeffect consists in dislodging of negative electrical charges from the surface of a metal plate (cathode) under exposure to ultraviolet light. Stoletov also confirmed that it is necessary to illuminate the plate with ultraviolet rays to observe the photoeffect; here different metals show different sensitivities to the incident light. Stoletov also established that the photoeffect is without inertia. He then determined the photocurrent as a function of the potential difference between a metal disk and a grid and recorded curves of this dependence. Analyzing these curves, Stoletov concluded that a saturation current exists. Studying the dependence of the photocurrent on the energy of the incident light, he found that it is directly proportional to the energy of the light striking the plate. These and other relationships discovered by Stoletov enabled him to conclude that: "No matter what the mechanism of the active-electrical discharge (Stoletov referred to the photoeffect as 'active-electrical phenomena.' – B. S.), we are correct in regarding it as a certain current of electricity, with the air (by itself or owing to the presence of foreign particles in it) acting as a poor conductor. The apparent resistance to this current is not subject to Ohm's law, but it has a definite magnitude under definite conditions."

Stoletov began to acquire students. They went on to work both within the walls of Moscow University and in other educational institutions of Russia. One of the first was V. A. Mikhel'son. He graduated from Moscow University in 1883 and was retained there. He became a professor of the Moscow Agricultural Institute in 1894. Mikhel'son published studies in various fields of physics. We note here that he was the first to investigate the distribution of energy in the spectrum of the black body by statistical methods. By following his example, Wien was later able to derive the law named for him. Mikhel'son also worked on the theory of combustion and many other subjects.

Another of Stoletov's students, N. N. Shiller, was a talented physicist. Shiller graduated from Moscow University in 1868 and remained to work with Stoletov. Eventually he held positions as a professor at Kiev University and Rector of the Khar'kov Technical Institute. Shiller worked in thermodynamics. In this area of physical science he was the originator of the axiomatic trend subsequently developed by Caratheodory and others.

Stoletov's students included R. A. Kolli and D. A. Gol'dgammer, who worked first at Moscow and then at the Kazan' University, and A. P. Sokolov, who became a professor at Moscow University and is credited with organization and expansion of the physics practicum.

In speaking of Stoletov's role in the development of the science in Russia, we must not omit mention of his struggle for materialism in physics. He criticized the idealistic utterances of Mach and Ostwald in a series of papers. Stoletov was able to imbue his students with his advanced philosophical views, and most of them came to hold materialistic convictions, some of them even speaking out against physical idealism.

As a result of Stoletov's work, Moscow University physics held a leading position in Russian and a prominent one in world science. Stoletov was well known abroad and enjoyed merited authority. He participated actively in no small number of conferences, congresses, etc.

In 1893, N. A. Umov, an alumnus of the university and at the time a professor at the University of Odessa, was invited back to become a professor of physics at Moscow. Umov had defended his doctorate thesis on "The Equation of Motion of Energy in Solids" at Moscow University in 1874. In it, Umov treated energy of any form as distributed in space and spoke of its localization and density at each point. This formulation of the problem was new and progressive for the 1870s. Although Maxwell's theory had already been published, it was not yet widely recognized among physicists. Most of them were adherents of the theory of long-range action. From the standpoint of this theory, it made no sense to speak of localization of electromagnetic energy in space or of the localization of gravitational-field energy. Moreover, even for the internal energy of a heated body, it was possible, strictly speaking, to use the energy-localization concept only for macroscopic scales, treating the body as continuous. On the other hand, recognizing that the intermolecular forces were treated as long-range forces, it made no sense to introduce the energy-localization concept at the molecular level either.

In his dissertation, Umov came out in favor of short-range action. He proposed that any form of energy reduces in the final analysis to kinetic energy of macroscopic bodies or "latent media." Since Umov did not derive any models of the motion of latent media, he was essentially using the notion of the physical field.

Introducing the concept of energy density and the energy flux density vector, Umov wrote the law of energy conservation in differential form. He then applied the theory of motion of energy to a whole series of physical processes, including electrodynamic phenomena. However, he did not touch upon the propagation of energy in an electromagnetic field. He apparently believed that it was still too early to consider the motion of energy in Maxwell's theory, since this theory was not yet generally accepted.

Later, in 1884, Poynting investigated the problem of energy motion in an electromagnetic field. This study of Poynting can be regarded correctly as a concrete application of Umov's general idea to the electromagnetic field.

Umov's work was not properly appreciated in his time. His opponents rejected its basic idea, that of the localization and motion of energy. With few exceptions, the authors of later papers that discussed energy localization and motion problems made no mention of his work. Neither, for that matter, did Poynting make mention of it.

Umov's later work, both theoretical and experimental, some of which was done within the walls of Moscow University, was devoted to various problems of physics: problems in magnetism, optics, etc. In particular, Umov is credited with an original derivation of the formulas of the Lorentz transformation (1910). Umov considered the question: what are the formulas for the transformation of variables (coordinates and time) in the wave equation that leave this equation invariant? Umov showed that, among others, the formulas of Lorentz transformation are such formulas.

Umov was a superb lecturer. After Stoletov's death, he began to teach the course in experimental physics. His lectures were profound in content and brillant in form. He made much skillful use of demonstrations, which were presented with the assistance of I. F. Usagin.

Umov's great service to physics at the university was his insistent agitation for construction of a Physics Institute building. A plan for this building was prepared under his direction in 1897 and the building went up in 1903. In the fall of that year, delivery of physics lectures began in the institute's great auditorium. Scientific work developed on a broad front in the institute, along with training of physicomathematical-department students in experimentation.

Umov took an active part in scientific-community activity. He read public lectures, belonged to numerous scientific societies, and took part in the work of the publishing houses. Finally, Umov had broad contacts with foreign scientists and traveled abroad more than once.

A third prominent Moscow University physicist of the prerevolutionary era was P. N. Lebedev. Stoletov recruited him for Moscow University in 1891 after he had acquired an education in physics abroad. At the university, Lebedev at first worked as a nonstaff collaborator, but in 1900 he was elevated to a professorship.

Even during his period abroad, it had occurred to Lebedev that molecules can be treated as sources and receivers of electromagnetic radiation to explain intermolecular forces. At Moscow, Lebedev resolved to verify this hypothesis experimentally. However, this could not be done at once. He therefore turned to study of the "pondermotive"-force interaction between macroscopic sources and receivers of various kinds of waves. Lebedev investigated the action of electromagnetic and acoustic waves on appropriate resonators. He established conditions under which the action of incident waves on the resonators would result in repulsion and attraction, etc.

He reported his results in a paper entitled "An Experimental Study of the Ponderomotive Action of Waves on Resonators," which he defended as a doctorate thesis in 1900 before being appointed a professor at Moscow University.

The action of waves on resonators that Lebedev had detected implied the existence of light pressure on solids. The existence of this pressure also followed from Maxwell's theory, and the magnitude of this pressure was also determined from his theory. Therefore measurement of the pressure of light on solids was a further experimental confirmation of the Maxwell theory.

Having overcome great experimental difficulties, Lebedev measured the pressure of light on solids and obtained a value that agreed closely with Maxwell's theory.

Lebedev spoke on the results of his work for the first time in 1899 and then published them in 1900. Lebedev's experiments attracted a great deal of attention from the scientific community and won him fame as a remarkable experimentor.

Lebedev later accomplished an even more difficult experimental task. He measured the pressure of light in gases. He made a preliminary report in 1908 and published his results in 1910.

In addition to his classical work on light pressure, Lebedev authored several other experimental studies. We note here only one of them. In 1895 he described experiments with electromagnetic waves having wavelengths much shorter than those with which Hertz had worked. While Hertz had used a wave 0.5 meter long, Lebedev succeeded in producing waves only 6 mm in length.

Lebedev's great accomplishment was his training of the whole constellation of physicists who formed the famous Lebedev school. Lebedev assigned his students subjects for scientific research and followed their work on a daily basis. In his laboratory he organized a colloquium whose sessions discussed scientific problems and, in particular, the work of each of his students.

Since lack of space prohibits a detailed account of all the work of Lebedev's school, we take note of only the most talented of his students.

The first name that comes to mind is the famous Soviet scientist P. P. Lazarev, who was elected an Academician in 1917. He had begun to work with Lebedev back in 1905. At first, he investigated the chemical effects of light, then the temperature distribution in a rarefield gas enclosed between two walls and other problems. Lazarev's later work in biophysics was most widely recognized; here he developed the ionic theory of excitation and adaptation theory and established the so-called unified law of stimulation.

V. K. Arkad'ev was another outstanding student of Lebedev's. He went to work with Lebedev in 1907. His first studies were devoted to the behavior of ferromagnetics in electric fields. In 1913, Arkad'ev made the first observation of selective absorption of electromagnetic waves in ferromagnetics, which later came to known as ferromagnetic resonance. Later he developed a theory of the electromagnetic field in ferromagnetic metals, which, together with his other work, formed the foundation of modern magnetodynamics in the Soviet era.

Future Moscow University professors—N. A. Kaptsov, A. B. Mlodzeevskiĭ, A. K. Timiryazev, and others—began their work under Lebedev's supervision.

The gifted physicist A. A. Eĭkhenval'd arrived at the university in 1906 and worked there until 1911. Eĭkhenval'd is known for his experiments to determine the magnetic fields of convection currents and also of displacement currents in dielectrics (1900–1904).

Astronomy made great progress at Moscow University during the latter half of the Nineteenth Century. As we noted above, an astronomical observatory had been built for the university back in 1831 under the direction of Prof. Perevoshchikov. After Perevoshchikov moved to St. Petersburg in 1851, direction of the observatory was turned over the A. N. Drashusov, who worked on position determinations of circumpolar stars.

In 1845, B. Ya. Shveĭtser transferred from Pulkovo to Moscow University, and when Drashusov departed in 1856 he became Director of the astronomical observatory. He investigated the Moscow gravitational anomaly and discovered four new comets.

In 1855, F. A. Bredikhin, who was to become an outstanding Russian astronomer, graduated from Moscow University. He became a professor of the university in 1865, a position in which he remained for about 30 years. In 1873, after Shveĭtser's death, he became director of the observatory.

Bredikhin was the first astronomer of real stature at Moscow University. He laid the foundations for astrophysical study of the sun, comets, and meteors. He conducted brilliant investigations toward a theory of comet tails.

After being elected an Academician, Bredikhin moved to St. Petersburg in 1890 and took over the position of Pulkovo Observatory director. He was succeeded at the Moscow University Observatory by V. K. Tseraskiĭ, who had already attained professorial rank. The Moscow Observatory was equipped further under Tseraskiĭ. It acquired a 15-inch astrograph and several other instruments.

Tseraskiĭ was one of the founders of astrophotometry. He authored numerous astrophotometric studies of celestial bodies. Tseraskiĭ educated a whole retinue of Moscow astronomers who would flower during the Soviet era.

In 1911, scientific development at Moscow University sustained a heavy blow, from which it was unable to recover before the beginning of the October Revolution. In that year, as a sign of protest against police high-handedness at the university, more than 100 democratically inclined professors and instructors left the university. Among them were Physics Professors Umov, Lebedev, and Eĭkhenval'd and Professor of Astronomy Tseraskiĭ. Scientific research in physics went into a slump, and work in the field of astronomy was also set back sharply.

DEVELOPMENT OF RESEARCH IN PHYSICS, GEOPHYSICS, AND ASTRONOMY DURING THE PREWAR SOVIET YEARS (1917-1941)

The Great October Revolution breathed new life into Moscow University, which had disintegrated during the years of political reaction. From the very first days of the Soviet state, its government and V. I. Lenin personally gave a great deal of attention to the development of science and preparation of cadres in the country's higher educational institutions. Student enrollment was doubled in 1918. Here attention was paid to changing the social composition of the student body. A workers' faculty was created at the University in 1919 to instruct worker and peasant youth. The graduate program began to function in 1923. An institute for scholarship students was founded in 1927, so that the graduate program could be designed primarily for representatives of the worker and peasant classes.

Special attention was devoted to improvement of study plans and programs in support of the preparation of specialists who would meet the country's needs. The Subject Commissions established early in the 1920s in the various departments played a major role in this work. They were headed up by the ranking professors of the university. The Subject Commisions grouped instructors in related disciplines; they also included representatives of the student body who were elected at student assemblies.

The teaching process was improved continuously at the university. New lecture courses (Theory of Oscillations, Thermodynamics, Radioactivity, Electron Theory, X-ray Structural Analysis, etc.) were offered by the physicomathematical department, the general physics practicum was modernized significantly, a special physics practicum was created, and student on-the-job training was introduced. Training of students became increasingly specialized in the newly organized special departments, the number of which had increased to 14 by 1941. Even before the war, the measures taken enabled the physics department to handle the systematic training of large numbers of highly qualified physicists for work in the country's scientific research institutes and colleges.

The first scientific school of Russian physicists, which Lebedev had created at Moscow University, began to develop rapidly during the Soviet years and make major advances in various areas of physical science. In 1922, the Institute of Physics and Crystallography, in which research work was developed on a broad scale, was set up in the Physicomathematical Department.

Work in the field of electromagnetism was especially important. It was headed by V. K. Arkad'ev, who was elected a Corresponding Member of the USSR Academy of Sciences in 1927. He was the founder of the first school of magnetologists in our country. Back in 1919, during the turmoil of the Civil War, Arkad'ev had organized a magnetics laboratory at Moscow University, and in 1931 it was renamed the Maxwell Laboratory of Electromagnetism. Academician B. A. Vvedenskiĭ, Academician of the Belorussian Academy of Sciences N. S. Akulov, Prof. A. A. Glagoleva-Arkad'eva, V. A. Karchagin, E. I. Kondorskiĭ, N. N. Malov, S. N. Rzhevkin, R. V. Telesnin, K. F. Teodorchik, and others began their scientific careers in this laboratory. The work of the laboratory was concentrated on electromagnetic oscillations and waves and investigation of peculiarities of their propagation in metals.

Glagoleva-Arkad'eva continued Lebedev's work on the generation and investigation of short electromagnetic waves. Using a so-called mass radiator in 1923, she generated waves with lengths from 82 microns to several centimeters in length. These experiments completed construction of the electromagnetic wavelength scale, since the waves obtained by Glagoleva-Arkad'eva filled the gap between the infrared part of the optical spectrum and the radio frequency band.

With his students, Arkad'ev investigated the magnetic properties of matter in magnetic fields of various frequencies. He developed a theory and originated a new subdivision of the science—magnetic spectroscopy. The results of these studies formed the basis for our modern concepts of ferromagnetism. Broad opportunities for their practical application in developing methods for magnetic analysis and defectoscopy of metals were indicated at the same time. This extensive cycle of studies was summarized by Arkad'ev in his 1934–1936 monograph "Electromagnetic Processes in Metals."

A physics division that soon grew into a physics department was created at Moscow University in 1930–1931. A number of new chairs and laboratories were instituted at the same time. Thus, the chair of magnetism under Arkad'ev's student N. S. Akulov was separated from the electromagnetism laboratory in 1931.

In 1928, Akulov established a general law of induced anisotropy that enabled him to explain the behavior of the magnetostriction, electrical-conductivity, thermal-emf, and other characteristics of ferromagnetic metals. He explained the phenomena in ferromagnetics whose signs remain unchanged on a change in the sign of the magnetic field (Akulov's theory of parity effects). Akulov's theoretical conceptions were the basis for many papers written by his students. The basic relationships in mechanomagnetism—the relationships between the mechanical and magnetic properties of ferromagnetics—were established (K. P. Belov and others); the technical magnetization curve was studied for undeformed and elastically deformed iron and nickel single crystals (N. L. Bryukhatov, L. V. Kirenskiĭ); the powder-figure technique on which magnetic flaw detection is based was elaborated (Akulov-Bitter method); a theory of coercive force and magnetization curves was derived (E. I. Kondorskiĭ). Several original instruments were also designed (magnetic defectoscopes, anisometers, the magnetic micrometer, and others) and made it possible to improve magnetic measurement techniques greatly.

The research of the magnetism chair was summarized by Akulov in the monograph "Ferromagnetism." He was awarded a USSR State Prize in 1941 for applying his theory of ferromagnetism to flaw detection in metals.

A chair of x-ray structural analysis was created in the physics department in 1930–1931 and headed by S. T. Konobeevskiĭ, who was elected a Corresponding Member of the USSR Academy of Sciences in 1946. Professors V. A. Karchagin and A. A. Glagoleva-Arkad'eva participated actively in its organization.

In a 1920 x-ray study of the structure of rolled metals, N. E. Uspenskiĭ, a student of Lebedev's, and S. T. Konobeevskiĭ had established a certain orientation of crystals that appeared as a result of deformation. These studies, which laid the groundwork for x-ray structural analysis of wrought metals, were expanded by G. S. Zhdanov and V. I. Iveronova. The chair devoted most of its attention to development of methods and design of instruments for x-ray structural analysis applications.

The same period saw organization of the chair of molecular and thermal phenomena, which later was renamed the chair of molecular physics. It was headed by Lazarev's student A. S. Predvoditelev, who was elected a Corresponding Member of the Academy of Sciences in 1939.

During the Soviet era, the department's first studies in the field of molecular physics were made by S. A. Boguslavskiĭ, who pointed out ways in which thermodynamic variables could be calculated in principle from the standpoint of statistical physics, and applied this method to various problems in molecular physics.

Umov's former student A. I. Bachinskiĭ did important work in thermodynamics and molecular physics. His research was devoted to the viscosity of fluids, associations of their molecules, and the influence of temperature on surface tension.

The physics of combustion and molecular physics emerged as basic interests of the molecular-physics chair. This work was done in close collaboration with the F. É. Dzerzhinskiĭ Thermal Engineering Institute. Laws of flame-front propagation in homogeneous mixtures were established, the integral and spectral emissions of the flame were studied, the causes of forced ignition of combustible mixtures of various gases were clarified, and the influence of catalysts and various impurities on heterogeneous combustion was established (diffusion theory of A. S. Predvoditelev). Predvoditelev and his students summed up their results in the monograph "The Combustion of Carbon," which was recognized in 1950 with a USSR State Prize.

At the same time, the chair was investigating the thermal characteristics of all Soviet-made steels over a broad range of temperatures at the request of the "Élektrostal'" plant. These studies resulted in the development of new procedures for thermal measurements and accumulation of a great wealth of tabulated data that subsequently appeared in all metallurgical handbooks.

The chair also gave a great deal of attention to the kinetics of chemical conversions in the electric discharge and to heat-exchange processes at high flow velocities. These studies proved to be especially timely with the rapid development of rocketry.

The work of Prof. B. A. Il'in, once a student of Academician Lazarev, was contiguous to molecular physics: he originated a new trend in the department, the study of the physicochemical processes at the interfaces between various media. He also developed a molecular-electronic theory of adsorption forces.

V. K. Semenchenko, a student of S. A. Boguslavskiĭ and later a Professor, obtained important results in the theory of strong electrolytes and problems of solubility, association, and adsorption in solutions.

Studies of short electromagnetic waves, gas-discharge physics, and electronics were developed broadly. They were directed by Lebedev's students N. A. Kaptsov and V. I. Romanov. This work was of great practical importance, since it revealed the physical nature of processes that take place in vacuum tubes and other electronic devices.

In connection with this area of research we should note the theoretical studies of S. A. Boguslavskii (1922–1923) that were devoted to motion of electrons in electric and magnetic fields and to the establishment of the laws governing the flow of electron currents in vacuum devices. Note should also be taken of Prof. Romanov's work on the anomalous dispersion and absorption of electromagnetic waves.

In 1930, a chair of electronic and ionic processes was organized in the physics department and headed by Prof. N. A. Kaptsov. Investigation of elementary processes in the gas discharge and study of cathode-electronics problems emerged as its main areas of interest. In recognition of industrial requirements, much attention was given to phenomena that occur in electronic devices.

Kaptsov developed a theory of the corona discharge and found the conditions under which it becomes a spark discharge, established mechanisms of development of the gas discharge during buildup of electron avalanches, puncture of the gas gap, and the appearance of transitional gas-discharge forms. In 1927 he also succeeded in explaining the mechanism by which microwave oscillations are set up in cavity systems by formation of electron bunches in the electron flux. This effect determines the operation of the magnetron and the backward-wave tube among the devices important for microwave electronics.

Kaptsov's numerous students obtained many interesting and practically important results. The nature of secondary electron emission was established (P. V. Timofeev *et al.*); a theory of the mobility of electrons in plasma was derived (S. D. Gvozdover); the scattering of a negative space charge of electrons by positive ions was investigated and a method developed for measurement of very low pressures (G. V. Spivak); the gas-discharge plasma was studied by a probe-characteristic technique and the influence of metastable atoms on the parameters of the gas discharge was investigated (G. V. Spivak, É. M. Reĭkhrudel', and others).

A laboratory of electroacoustics and low currents was organized in the department by Prof. S. N. Rzhevkin in 1928. This laboratory provided intensive training in physical acoustics and carried out an important series of studies in physiological and architectural acoustics, as well as ultraacoustics. The results were summarized in Rzhevkin's monograph "Hearing and Speech."

In 1925, at the initiative of S. I. Vavilov, the university invited L. I. Mandel'shtam to take over the chair of theoretical physics and optics; he was elected a Corresponding Member of the USSR Academy of Sciences in 1928 and an Academician in 1929.

Academician Mandel'shtam, the 100th anniversary of whose birth was widely noted by the scientific community in 1979, formed a new scientific school at Moscow University, one whose representatives worked in the areas of physics of oscillations, optics, and molecular and theoretical physics. Among his students were academicians A. A. Andronov, G. S. Landsberg, and M. A. Leontovich, Corresponding Members of USSR Academy of Sciences V. V. Migulin and S. M. Rytov, Academician of the Kirgiz SSR P. A. Ryazin, Professors A. A. Vitt, G. S. Gorelik, M. A. Divil'kovskiĭ, S. P. Strelkov, M. I. Filippov, S. É. Khaĭkin, S. P. Shubin, and others.

Throughout his lifetime, Mandel'shtam always attached special importance to the development of oscillation theory. It was his belief, clearly demonstrated in his work, that great progress could be made in solution of the most complex problems of optics, acoustics, engineering mechanics, astronomy, chemistry, and other divisions of science and engineering if they were examined from a consistent oscillatory view-point, using concepts and mathematical formalisms borrowed from oscillation theory.

Research in the physics of oscillations and radio physics developed especially rapidly after 1930, when the chair of oscillations was organized in the department under L. I. Mandel'shtam. Back in 1925, his graduate student A. A. Andronov had begun theoretical studies of oscillatory processes in nonlinear systems. They were of great importance for the development of radioengineering and nonlinear devices for use in generating, converting, and amplifying electrical signals. Using the mathematical apparatus developed by Poincaré and A. M. Lyapunov, Andronov produced a theory of the generation of undamped oscillations and was the first to introduce the now widely used term "self-oscillation." Andronov's theoretical results laid the groundwork for a new trend in the study of oscillations—the theory of nonlinear oscillations. This theory was developed further by Vitt and Khaĭkin. G. S. Gorelik extended resonance theory to systems with periodically varying parameters. Mandel'shtam's students discovered a number of new phenomena: resonance of the second kind, combination resonance, acoustic capture, the frequency-division method, and others. S. P. Strelkov investigated self-oscillatory processes in aerodynamic flows. His results were used in the design of high-powered wind tunnels. K. F. Teodorchik made a significant contribution to development of the theory of self-oscillatory systems. The scientific results obtained by Mandel'shtam's school at Moscow University were of fundamental importance for the development of radio, acoustics, optics, the theory of servo and control systems, and the stability theory of dynamic systems. Mandel'shtam's own work on oscillation and radiopropagation theory, which was done jointly with his closest co-worker, Academician N. D. Papaleksi, was recognized in 1936 with the USSR Academy of Sciences D. I. Mendeleev Prize and in 1942 with a USSR State Prize.

No less significant results were recorded by Mandel'shtam's school in the field of optics. These studies were done in the optics laboratory and theoretical section of the Physics Department's Institute of Physics. In 1926, Mandel'shtam published a paper based on some of his earlier studies (1919–1921) in which he predicted the existence of spectral-line fine structure in Rayleigh scattering. The French physicist L. Brillouin had arrived at similar conclusions (1924). This phenomenon came to be known as Mandel'shtam-Brillouin scattering. Its existence was confirmed experimentally in 1930 by E. F. Gross. In 1931, Mandel'shtam was awarded the V. I. Lenin Prize for prediction and study of this effect.

In a study of the scattering of light in quartz, Mandel'shtam and G. S. Landsberg, who had been working in the University's Theoretical Physics Section since 1923, detected the appearance of new lines (satellites) at positions symmetric about the Rayleigh line. This phenomenon, which came to be known as combination [Raman] light scattering and made it possible to establish the frequencies of natural molecular vibrations, resulted in the emergence of a new trend in molecular spectroscopy. It opened up broad possiblities for the study of the structure of matter, intermolecular and intramolecular interactions, and the use of Raman spectra for analytic purposes. Simultaneously with discovery of this phenomenon by Soviet physicists, it was detected by the Indian physicists C. V. Raman and K. S. Krishnan in benzene.

The lectures and seminars that Mandel'shtam conducted at the university from 1925 to 1944 were of special importance. They were devoted to a broad range of the most urgent problems of physics, in which the lecturer gave an exceptionally profound analysis of the present state of each, without concealing the existing difficulties, and pointed the way to original solutions of the most complex problems. These lectures attracted a broad audience of physicists of all ages and ranks from all over Moscow. Academician Papaleksi wrote: "Mandel'shtam's lectures and seminars at Moscow University were outstanding events in the scientific life of our country.... These lectures... were among his most inspired and surpassing creations."

In 1930, the optics laboratory at the university was headed by G. S. Landsberg, who was elected a Corresponding Member of the USSR Academy of Sciences in 1932 and an Academician in 1946. Working with his students, he applied the Raman scattering technique to study of the molecular structure of individual hydrocarbons. In 1932, M. A. Leontovich and Mandel'shtam produced a theory of light scattering in solids. Mandel'shtam and Landsberg investigated the propagation of ultrasound in gases, liquids, and crystals. With Leontovich, Mandel'shtam derived a relaxation theory of the absorption of ultrasound in liquids.

Beginning in 1930, the optics laboratory worked on the development and practical use of emission spectral analysis methods for metals and alloys. This work was done in collaboration with the Moscow Automobile Works. Under Landsberg's direction, methods for qualitative and quantitative spectral analysis of steels, cast irons, and alloys were developed; original instruments were also built for these purposes. In 1941, Landsberg was awarded a USSR State Prize for his work in spectral analysis.

Among the prewar studies in optics, we should also take note of an investigation by A. A. Vlasov and V. S. Fursov, who derived classical and quantum theories of the spectral line broadening of gas atoms on collisions between them.

S. I. Vavilov played a major role in the life of the physics department. It was here that he began his teaching career in 1918 as a practicum instructor; later he became a privatdozent, and in 1929 he was appointed to a professorship and the chair of general physics. In addition to his monumental and extremely productive work on the organization of this chair, elaboration of integrated study programs, and his radical revamping of the physics practicum, Vavilov originated the "optics" major in the department. In a short time, Vavilov surrounded himself with an influential group of young physicists at the university. V. V. Antonov-Romanovskiĭ, E. M. Brumberg, V. Ya. Sveshnikov, I. M. Frank, V. S. Fursov, and A. A. Shishlovskiĭ went to work in his laboratory.

Vavilov promoted research on luminescence at the university. He derived a theory of the quenching of luminescence in solutions by foreign impurities with Frank in 1931. Vavilov and Shishlovskiĭ studied the laws of fluorescence decay in dye solutions, and Vavilov collaborated with Brumberg in developing an experimental method for verification of the formulas for Brownian rotational motion. In 1928, Vavilov wrote his book "Experimental Bases of Relativity Theory," which is as valuable today as it was then. His work in optics and luminescence was recognized with four USSR State Prizes.

Vavilov was elected a Corresponding Member of the USSR Academy of Sciences in 1931 and an Academician in 1932; he was named scientific director of the State Optical Institute at Leningrad and was obliged to leave Moscow. However, even after departing the Moscow University physics faculty, he remained in close touch with it—a relationship that lasted for the rest of his life and had a strong influence on its development.

Beginning in 1931, research on luminescence in the physics department was headed by Vavilov's closest colleague, Prof. V. L. Levshin. In 1931, Levshin established the mirror symmetry of the absorption and luminescence spectra of solutions of many organic compounds (Levshin's rule). It permits inferences as to the energy-level structure of the molecules, their populations, and the probabilities of transitions between them, and is one of the basic relationships characteristic of molecular luminescence. The quantum-mechanical basis of the mirror-symmetry rule was stated in 1939 by D. I. Blokhintsev and developed later by B. I. Stepanov *et al.* During these years, Levshin was doing pioneering work in optical study of molecular association in dye solutions. In 1933, working with his graduate student V. V. Antonov-Romanovskiĭ, he made the country's first quantitative study of crystal phosphor luminescence. The hyperbolic law of crystal phosphor luminescence decay was established, proving that the emission is of recombination nature. Levshin's work on luminescence was honored with two USSR State Prizes (in 1951 and 1952).

Theoretical physics research at Moscow University dates from the time of N. A. Umov. In 1921, after a suggestion by A. A. Eĭkhenval'd, a chair of theoretical physics was created with S. A. Boguslavskiĭ at its head. The latter did a great deal to improve the teaching of theoretical physics and was the first to make study of modern divisions of physical science a requirement. In addition to those of Boguslavskiĭ's studies that were mentioned above, we should note his research on the quantum theory of pyroelectricity, crystal structure, and the theory of fusion.

Mandel'shtam took over the chair of theoretical physics in 1925 and was succeeded in 1931 by I. E. Tamm, who was elected a Corresponding Member of the USSR Academy of Sciences in 1933 and an Academician in 1953. In 1931, Tamm derived a quantum theory of the photoeffect in metals and demonstrated the difference between the volume and surface photoeffects. In 1932, he argued for the existence of special electron levels on the surfaces of crystals—levels from which an electron can neither enter the crystal nor leave it. These "Tamm levels" play an important role in solid-state physics. Blokhintsev studied the influence of periodic structure in solids on the Hall effect and other phenomena.

At the USSR Academy of Sciences Institute of Physics in 1934, S. I. Vavilov and P. A. Cerenkov discovered the emission of pure liquids under γ-irradiation and showed that it is not luminescence. In 1937, Moscow State University Physics Department professor I. E. Tamm and I. M. Frank of the USSR Academy of Sciences Institute of Physics presented a theory of this phenomenon and explained its appearance in terms of motion of electrons at ultrarelativistic velocities in the medium. The work in which the Vavilov-Cerenkov effect was observed and its nature was explained, which is among the outstanding achievements of Soviet science, was recognized in 1946 with a USSR State Prize and in 1958 with the Nobel Prize.

A. A. Vlasov's candidate's dissertation, which he defended in 1934, began the elaboration of the theory of the electron plasma. He advanced new concepts of the development of long-range and collective interactions of charged particles in plasma. In 1937, he derived the fundamental kinetic equation that became the basis of contemporary plasma theory and came to be known as "Vlasov's equation." These studies of Prof. Vlasov were recognized with the Moscow State University Lomonosov Prize in 1945 and the Lenin Prize in 1970.

In 1940, Ya. P. Terletskiĭ established stability conditions for electron motion in the betatron and submitted an idea for building an iron-free pulsed betatron. The Moscow State University Lomonosov Prize was awarded for these studies in 1948 and the USSR State Prize followed in 1951.

The geophysical research that began with Lomonosov, P. I. Strakhov, and M. F. Spasskiĭ was also further developed after the October Revolution. Scientists from various departments of the university took part in this work.

The investigations of the Kursk Magnetic Anomaly that were conducted by the Special Commission in the Presidium of the All-Union Council of the National Economy (VSNKh) under the direction of Academicians I. M. Gubkin and P. P. Lazarev were of enormous practical value. Many university scientists (Profs. N. M. Nikiforov, A. A. Mikhaĭlov, L. V. Sorokin) and students, among them the future academicians G. A. Gamburtsev and M. A. Leontovich, became active participants in these studies. Their expedition made observations at more than 10,000 points, making it possible to prepare an extremely detailed map of the Kursk Magnetic Anomaly.

A new direction in science—oceanic physics—is associated with the name of academician V. V. Shuleĭkin, who was the first to apply methods of theoretical and experimental physics to study of physical phenomena in the seas and oceans (currents, waves, thermal processes, emission and absorption of radiant energy, etc.). In 1944, Shuleĭkin organized and headed the chair of marine and inland waters physics in the physics department of Moscow State University and set up the country's first program to train specialists in the field.

Astronomical research developed vigorously at Moscow University during the Soviet years. The Moscow school of astronomers that grew up around D. M. Perevoshchikov, F. A. Bredikhin, V. K. Tseraskiĭ, and P. K. Shternberg won world-wide recognition. The many-sided activity of Shternberg, Director of the Moscow Astronomical Observatory, a revolutionary, and a Bol'shevik, was particularly important. A noted specialist in positional astronomy and gravimetry, Shternberg educated a whole constellation of outstanding Soviet astronomers. Among his students: Academician A. A. Mikhaĭlov, Corresponding Members of the USSR Academy of Sciences S. N. Blazhko and S. V. Orlov, and Professors S. A. Kazakov and I. F. Polak.

The organization of several scientific centers at Moscow contributed to the successful development of astronomical research. The State Astrophysical Institute was set up in 1921 under V. F. Fesenkov, and the Astronomical-Geodetic Institute under Blazhko at Moscow State University in 1922. In 1931, the two establishments were combined to from the P. K. Shternberg State Astronomical Institute (GAISh), which became part of Moscow University. It was directed originally by the mathematician A. A. Kancheev, but from 1936 by Fesenkov, who had been elected an Academician. The former astronomy chair of Moscow State University was replaced by the chairs of gravitation (Prof. L. V. Sorokin), celestial mechanics (Prof. N. P. Moiseev), stellar astronomy (Corresponding Member of the USSR Academy of Sciences P. P. Parenago), and astrophysics (Acad. V. G. Fesenkov). The chair of comet astronomy (Corresponding Member of the USSR Academy of Sciences S. V. Orlov) was created later. The astronomy chair (Corresponding Member of the USSR Academy of Sciences S. N. Blazhko) was renamed the chair of positional astronomy.

Work on variable stars was greatly expanded by Blazhko, who discovered a number of new variables and established the periods of several antagols (Blazhko effect). Young astronomers who were later to become prominent scientists—Corresponding Members of the USSR Academy of Sciences P. P. Parenago and M. S. Zverev and Prof. B. V. Kukarkin—worked in this area during the 1930s. They aided in implementation of an extremely broad-scale program of planned research on variable stars and clusters. Note should also be taken of the work of Prof. B. A. Vorontsov-Vel'yaminov in determining the nature of hot stars, novae, and planetary nebulae, which began in 1930.

Fesenkov directed an extensive positional-astronomy program. Specially developed original photometer systems were used to investigate the brightness of stars, the light of the moon, the zodiacal light, and the optical properties of the atmosphere and to photograph the Milky Way. It was Fesenkov's idea to build a solar thermo-integrator, which his student G. F. Sitnik used to study sunspots and determine their temperatures. É. R. Mustel', another student of Fesenkov's, who was eventually elected a Corresponding Member of the USSR Academy of Sciences, developed theories of stellar atmospheres and novae. Fesenkov developed several cosmogonic theories of the origin of stars and planetary systems and the evolution of the sun.

The university's astronomers devoted a great deal of attention to positional-astronomical work. Prof. S. A. Kazakov determined star coordinates with the meridian circle. These measurements were substantially improved by Corresponding Member of the USSR Academy of Sciences M. S. Zverev. University positional astronomers also directed the work of numerous observatories in our country and abroad in compilation of the Fundamental Catalog of Faint Stars.

The studies of F. A. Bredikhin, the founder of comet astronomy, were continued by Corresponding Member of the USSR Academy of Sciences S. V. Orlov. His work advanced the mechanical theory of comet shapes; he analyzed the head and tail structures of comets and studied the brightness of their emission and its spectral composition. A USSR State Prize was awarded for this research in 1943.

Work in celestial mechanics was also developed. This was originally under the direction of Academician V. V. Stepanov, with Prof. N. D. Moiseev taking over later. In the first stage of this program, the motions of celestial bodies were analyzed with allowance not only for Newtonian gravitational forces, but also for the resistance of the cosmic medium, the gravitational influence of the Galaxy, etc. (nonclassical celestial mechanics). The qualitative methods of the theory of stability of motion that had been developed by A. M. Lyapunov (qualitative celestial mechanics) came into use in the mid-1930s in solving problems of the motion of celestial bodies.

The Russian school of gravimetrists had been founded by P. K. Shternberg. During the Soviet years, it flourished under the hands of his students, Academician A. A. Mikhaĭlov and Prof. L. V. Sorokin. They supervised the organization of many expeditions to various regions of the country to study the gravitational force field at the earth's surface. In 1930, gravimetric studies at sea and under water were begun at Sorokin's initiative. This work laid the foundations for Soviet marine gravimetry.

In 1936, a unique catalog of values of the force of gravity for 10,000 points was prepared at the Shternberg Institute (GAISh) under Mikhaĭlov's direction. The data collected were invaluable in determination of the figure of the earth, which indicated the eccentricity of its equatorial section. These data, which characterize the Earth's gravimetric field, have been used in exploration for minerals.

PHYSICS AND ASTRONOMY AT THE UNIVERSITY FROM 1941 to 1979

Scientific research and the training of physics cadres at Moscow University sustained a severe blow when Fascist Germany attacked our country. Classes were suspended and many students and instructors went to the front. Scientific research continued in the physics department during the difficult wartime years, both at Moscow and at evacuation sites (Ashkhabad and Sverdlovsk).

Classes resumed in the university's nonevacuated portion (at Moscow) as early as the beginning of February 1942, after the Hitlerites had been turned back at the gates of the city. The return of the evacuated portion was completed in June of 1943. Members of the physics department did everything in their power to assist the front with defense-related research.

The machine shop and experimental-design laboratory of the physics department produced radio, optical, aviation, and other instruments for the front. At Sverdlovsk, the GAISh expanded work of military importance on the time and solar services. Transmission of exact time signals from Moscow was not interrupted for a single day. In the optics chair, F. A. Korolev and coworkers did research on the shaped charge. The USSR State Prize was awarded to Korolev and N. L. Karasev in 1946 for development of optical methods and instruments for study of the shaped-charge explosion. Research was also conducted on fundamental physical problems. At Ashkhabad, Vlasov continued his development of a theory of the vibrational properties of the electron gas; S. P. Strelkov at Moscow worked on the problem of self-oscillations in wind tunnels.

P. L. Kapitza organized the chair of low temperatures in 1943 and headed it until 1948; in 1944, V. V. Shuleĭkin founded the chair of marine physics in the physics department, and S. N. Rzhevkin the chair of acoustics.

The gradual release of students, graduate students, and instructors from the Soviet Army to rejoin the faculty began in 1943. The returnees included V. S. Fursov, A. A. Samarskiĭ, N. P. Klepkov, V. L. Bonch-Bruevich, and others.

Fursov was sent to the laboratory that I. V. Kurchatov had organized early in 1943, where he did a great of scientific work and, at the same time, lectured in the physics department. Fursov was awarded three USSR State Prizes for his active work in this laboratory on solution of nuclear problems.

During the postwar years, physics acquired a dominant role among the natural sciences. Atomic and nuclear physics were developed rapidly, along with radiophysics and solid-state physics, including semiconductor physics. The advances in radiophysics, electronics, and semiconductor techniques triggered the rapid development of computer engineering, and electronic computing machines were built.

All of these important new trends in physics were advanced at Moscow University. During these years, special attention was given to the development of atomic and nuclear physics research and to the training of specialists in this area. Back in 1940, following a proposal of Academician Vavilov, a chair of the atomic nucleus and radioactive radiations had been organized in the physics department with Academician D. V. Skobel'tsyn as its director. In 1946, this chair formed the basis for organization of the Scientific Research Institute of Nuclear Physics of Moscow State University (NIIYaF MGU); Skobel'tsyn was named director of this institute (he was succeeded in 1960 by Academician S. N. Vernov. New chairs were organized and research was advanced on a broad range of atomic and nuclear physics problems.

The subject matter of scientific research in radiophysics was also broadened. A chair of microwave frequencies and a radiophysics division, which originally included the chairs of electronics, microwaves, oscillations, and acoustics, were organized. Later, a structure with divisions that incorporate chairs of related specialties was approved by the entire faculty. Scientific research work in the geophysics was further developed, and the chairs of earth physics (1945) and atmospheric physics (1947–1948) were established.

In 1948, the decision was taken to construct a new complex of buildings for Moscow State University on the Lenin Hills. The Physics faculty did a great deal of organizational work in connection with this project: laboratory areas for the new buildings were designed and scientific-research and teaching plant and equipment were ordered.

Moscow University physicists conducted a number of interesting scientific studies in the period 1945–1953, before the move to the new building in the Lenin Hills. Academician N. N. Bogolyubov, then a professor in the physics department, developed a consistent method for finding systems of meshing kinetic equations (Bogolyubov kinetic equation chains) for nonequilibrium systems; he also submitted a rigorous derivation of the equations of fluid dynamics. Bogolyubov succeeded in obtaining various types of kinetic equations for a system with short-range and long-range (and weak) forces by a consistent method. He was awarded a USSR State Prize in 1947 for his published monographs "Certain Statistical Methods in Mathematical Physics" (1945) and "Problems of Dynamic Theory in Statistical Physics" (1946). In 1947–1949, he worked on problems of quantum statistics and developed a method for approximate secondary quantization that later formed the basis for superconductivity theory.

In 1944, Prof. D. D. Ivanenko and I. Ya. Pomeranchuk (later Academician) showed that the energy of electrons in the betatron cannot be increased without limit because of electromagnetic radiation, and has a "radiation ceiling." Later, a theory of the "light-emitting" electron (synchrotron radiation) was developed by Ivanenko with Prof. A. A. Sokolov. In 1950, he shared a USSR State Prize with Pomeranchuk for these studies.

Mention should also be made of radiosonde studies of cosmic rays in the stratosphere. The protonic nature of the main primary cosmic ray flux was established as a result of these coordinated studies; it was shown that the particles that give origin to the penetrating cosmic-ray component (μ-mesons) and the electron-photon component are formed in multiple-production processes when they interact with atomic nuclei. Vernov was awarded a USSR State Prize in 1949 for these investigations, which essentially completed a certain phase in cosmic-ray research.

Work on a network of continuous-recording cosmic-ray stations was started during the same period. N. L. Grigorov, Yu. G. Shafer, and A. S. Muratov developed a precision cosmic-ray recorder for these measurements (USSR State Prize, 1951).

During the first postwar decade, physics developed rapidly at Moscow State University, and the breadth and volume of the studies soon passed the prewar level.

It can be said that the contemporary period in the development of physics at Moscow University began when the physics faculty moved to the new building in the Lenin Hills in 1953. This move opened the way for rapid development of the existing scientific directions; much attention was given in particular to new and important directions in contemporary physics. Close communications with the institutes of the USSR Academy of Sciences were set up to mark out promising areas for research, and noted scientists from the academic institutes were invited to lecture. Several of the chairs were reorganized, new ones were created, and the present-day structure of the physics faculty was nearly crystallized. Professor V. S. Fursov was named Dean and has been head of the department even since. Research is now being pursued on a broad front in practically all fields of physics in the physics faculty and the two institutes. The present-day physics faculty has 35 chairs in 6 divisions, as well as two scientific research institutes–the NIIYaF (Nuclear Physics) and the GAISh (Astronomy). These 6 divisions are as follows: 1) Division of Nuclear Physics (Acad. S. N. Vernov). 2. Division of Radiophysics (Prof. V. B. Braginskiĭ). 3. Division of Experimental and Theoretical Physics (Prof. L. V. Levshin). 4. Division of Solid State Physics (Prof. N. B. Brandt). 5. Division of Astronomy (Prof. E. P. Aksenov). 6. Division of Geophysics (Acad. V. A. Magnitskiĭ).

Let us dwell briefly on the most important achievements of the physics department during the period considered, i.e., from 1953 to the present.

The beginning of this period in the Division of Nuclear Physics and the NIIYaF was marked by significant expansion of the Institute as a result of completion of the new university buildings in the Lenin Hills. During this time, the institute was equipped with new apparatus, such as an installation for coordinated study of extensive air showers (EAS), a cyclotron, a betatron, a cascade generator, an electrostatic generator, and isotope-separation equipment.

New laboratories and practicums for nuclear and atomic physics and the institute's Dubna branch were created; the Division of Nuclear Physics was organized in the university physics department and the training of students and more highly qualified cadres was expanded.

At the end of the 1950s, what was at that time a unique installation for study of ultrahigh-energy rays (the EAS installation) was built at the institute. It aroused lively interest in the scientific world. Its importance in cosmic-ray research was stressed by outstanding scientists (Blackett, Bohr, Heisenberg, Rossi, Marshak, Yukawa, and others) who visited Moscow State University during that period. A new observation made with the EAS installation was that of a break in the energy spectrum of the primary cosmic radiation. These studies were later registered as a discovery by the Committee on Inventions and Discoveries in the USSR Council of Ministers (Academician S. N. Vernov *et al.*)

The launching of the first artificial earth satellites presented the institute with unique opportunities for the design of fundamentally new experiments in outer space.

In 1960, Vernov and A. E. Chudakov and staff members of USSR Academy of Sciences Institute of Terrestrial Magnetism, the Ionosphere, and Radio Propagation (IZMIR AN SSSR) were awarded the Lenin Prize for "the discovery and investigation of the earth's outer radiation belt and investigation of the magnetic field of the earth and moon."

In 1971, in recognition of his development of a quantitative theory of the earth's radiation belts and the associated geophysical phenomena, Prof. B. A. Tverskiĭ was awarded the Moscow State University Lomonosov Prize. Later experimental studies in the USSR and abroad confirmed the conclusions and predictions of this theory.

A new stratospheric method of planetary study of cosmic rays in the upper atmosphere using radiosondes was developed and first put to use to investigate the solar modulation of low-energy galactic cosmic rays (GCR).

The stratospheric measurements revealed an anomaly in the 11-year GCR cycle in the form of an unusual increase in their intensity during 1969–1972, with a simultaneous departure from the coupling with solar activity and a change in the energy spectrum of the particles undergoing modulation. The study of these phenomena is a new link in study of the properties of the interplanetary medium and processes on the sun. A 1976 Lenin Prize went to a group of scientists, including Doctor of Physicomathematical Sciences T. N. Charakhch'yan of the Moscow State University Scientific Research Institute of Nuclear Physics for stratospheric investigation of cosmic-ray flares on the sun and solar GCR modulation.

A natural extension of studies in the physics of cosmic rays was involvement of the institute in high-energy-physics research. The institute is now completing construction of a special scanning and measuring installation for this work. The high-energy-physics research program is based on close collaboration between scientists of the NIIYaF MGU and institutes of the USSR State Committee on Atomic Energy (GKAÉ SSSR) and the USSR Academy of Sciences.

Students and graduate students of the high-energy chair, directed by Academician and Lenin and State Prize winner A. A. Logunov (now Rector of Moscow University) work on their diplomate and dissertation studies both in the university and in several other institutes, including work on the largest Soviet accelerator at the Institute of High Energy Physics at Serpukhov.

Experimental and theoretical studies in the physics of the atomic nucleus and atomic physics are pursued in the NIIYaF.

Studying the scattering of particles by single crystals, Prof. A. F. Tulinov discovered a new physical phenomenon at the juncture of nuclear physics and solid-state physics. It has come to be known as the "shadow effect." It was found that when single crystals were bombarded by accelerated nuclear particles, the angular distributions of the nuclear-reaction and scattering products develop characteristic intensity minima (shadows) that reproduce the structure of the crystal in very high relief. A method for measuring the times of nuclear reactions was proposed and developed on the basis of this phenomenon, and the time characteristics of heavy-nucleus fission under n-, d-, and α-particle bombardment were studied. Procedures for studying the properties of solids were devised on the basis of the shadow effect and form the basis of protonography, a new physical trend. For the discovery and investigation of the shadow effect in nuclear reactions on single crystals, the group of NIIYaF co-workers headed by Prof. Tulinov was awarded a 1972 USSR State Prize, some time after Tulinov had been issued a discovery diploma (1967).

A discovery (registered in 1976) made by Moscow State University and Joint Institutes of Nuclear Research) JINR scientists played an important role in the development of study of meson-nucleus interactions; this was the phenomenon of resonant excitation of nuclei in meson-nucleus interaction processes, and its discoverers were Prof. V. V. Balashov and Candidate of Physicomathematical Sciences N. M. Kabachnik (Moscow State University Lomonosov Prize, 1978).

These studies led to a review of existing concepts of the mechanisms of other meson-nucleus processes: radiative capture of pions, photoproduction of mesons, pion-nucleus inelastic scattering. These studies formed the basis for many experimental investigations, which established the fact that resonant excitation of nuclei in meson-nucleus interaction processes is a universal property of nuclei and is associated with a singular and previously unknown form of motion of nuclear matter.

The organization of research in radiospectroscopy and quantum electronics and its development at the NIIYaF MGU are associated with the name of Academician A. M. Prokhorov. In 1973 he completed his cycle of studies "Development of a Range of Highly Sensitive Quantum Amplifiers and their Use in Long-Range Space Communications Systems and Radioastronomy," which won him a USSR State Prize in 1976 (Prof. L. S. Kornienko, Candidate of Physicomathematical Sciences G. M. Zverev); the sensitivity of radio receiving devices was greatly improved as a result of this work.

Recently, one of the basic research trends under development has been study of the interaction of laser and ionizing radiations with quantum- and opticoelectronics materials and, on this basis, exploration for new methods of controlling the characteristics of quantum generators. The idea of using a nonindependent discharge with an external ionization source to obtain generation of light was first advanced at the NIIYaF MGU. In 1976, Academician E. P. Velikhov and Doctors of Physicomathematical Sciences V. D. Pis'mennyĭ and A. T. Rakhimov were awarded the Moscow State University's Lomonosov Prize, and in 1978 Rakhimov and Senior Scientific Colleague I. G. Persiyantsev shared a USSR State Prize with scientists of other institutes and organizations for the cycle of studies "Development of Physical Principles, Design, and Investigation of Lasers Excited by Ionizing Radiation."

The physics of oscillations and waves, radiophysics, quantum radiophysics and laser optics, electronics, and acoustics have been developed in the Radiophysics Division. While L. I. Mandel'shtam had directed the formation of a generally recognized school of advanced studies in nonlinear oscillation theory at Moscow University in the 1920s and 1930s, a similar institution for theoretical and experimental study of nonlinear waves formed from the 1950s through the 1970s. Among the founders of this school was Academician R. V. Khokhlov, whose life was unfortunately cut short. His scientific interests were originally in the development of nonlinear problems of oscillation theory, where he is credited with important results. There is, for example, the highly productive Khokhlov technique for stepwise simplification of the short equations that describe almost sinusoidal oscillations in nonlinear systems; he was the first to point out the possibility of separating slow and fast motions in certain cases, thus making it possible to lower the total order of the equation system. Then he became interested in problems of the theory of nonlinear electromagnetic waves in the radio band. Of particular interest were his later studies of the theoretical and experimental bases of nonlinear optics, a field in which he collaborated with S. A. Akhmanov and which began to develop rapidly in the 1960s was the advent of powerful lasers. Here they succeeded in obtaining several important theoretical and experimental results: in 1962, in particular, they proposed a parametric tunable laser, which was built a few years later at practically the same time as the similar device produced by a group of American physicists. Khokhlov and Akhmanov were awarded a Lenin Prize in 1970 for their cycle of studies of nonlinear coherent interactions in optics. In later years, Khokhlov, at that time Rector of Moscow University, collaborated with his students in obtaining a number of important theoretical results in nonlinear acoustics.

We note that contemporary trends in nonlinear oscillation theory are being developed in the oscillations chair under the direction of Corresponding Member of the USSR Academy of Sciences Prof. V. V. Migulin.

We cite several other interesting studies completed in recent years by staff members of the radiophysics division.

L. V. Keldysh, Professor of the Chair of Wave Processes (now Academician Keldysh and head of the quantum radiophysics chair), working at the Academy of Sciences Physics Institute (FIAN) and part-time at the university, completed a series of pioneering studies in semiconductor physics (Lenin Prize, 1974). In these studies, which have won wide international recognition, he investigated a number of important problems in the theory of the interaction of electromagnetic radiation with semiconductors. Academician Keldysh developed a general theory of the tunnel effect and multiphoton ionization in solids. He predicted the dependence of semiconductor forbidden bandwidth on a constant external electric field. This effect is now known as the "Keldysh-Franz effect." For his study of semiconductors at high exciton concentrations, Keldysh was awarded a European Physical Society Prize (1974); he formulated the concept of condensation of excitons into mobile drops of metallic electron-hole fluid and produced a theory of this new and striking phenomenon.

Working with an original electron-microscope strobing procedure developed by the electronics chair, G. V. Spivak, V. I. Petrov, O. S. Kolotov and R. V. Telesnin discovered a previously unknown magnetization reversal mechanism in ferromagnetics. They were awarded a Moscow State University Lomonosov Prize in 1975 for a complex study of pulsed magnetization reversal in thin magnetic films. They also recorded the discovery of domain-wall rupture in ferromagnetics under the action of magnetic fields (G. V. Spivak, V. I. Petrov, R. V. Telesnin, 1975).

After a prediction by D. N. Klyshko, V. V. Fadeev and O. N. Chunaev made experimental observations of spontaneous decay, in a solid, of one or two incident-light photons into a pair of photons with different frequencies, which depend on the scattering angles—an effect due to the polarizability nonlinearity of bound electrons of the medium; this three-photon parametric scattering of light was registered in 1974 as a discovery and is now of great importance in solid-state spectroscopy.

V. B. Braginskiĭ developed a theory of threshold measurement for pulses acting on systems with small dissipation, and performed a series of high-precision limit measurements: he established the upper energy-density limit for gravity-wave bursts of extraterrestrial origin ($\approx 10^6$ erg/cm$^2\cdot$ Hz), obtained a Q of $5\cdot 10^9$ in mechanical cavity resonators, investigated the electromagnetic-friction effect of order $1/c^2$ that appears in the form of additional damping at the moving wall of an electromagnetic resonator, etc. In 1975, the Presidium of the USSR Academy of Sciences awarded Braginskiĭ the P. N. Lebedev Gold Metal in recognition of his work on systems with small dissipation in physical experiments.

Beginning in the mid 1950s, V. A. Krasil'nikov and L. K. Zarembo performed a series of studies in nonlinear acoustics (Moscow State University Lomonosov Prize, 1976). It was shown in their papers that nonlinear acoustic effects in liquids and solids are quite strongly in evidence under certain conditions and may have a strong influence on the propagation of elastic waves (for example, effects of harmonic generation in liquids and solids, nonlinear absorption, generation of forbidden harmonics in crystals under the influence of dislocations, and others were detected). Sensitive experimental methods were developed for investigation of nonlinear effects. This series of studies had considerable influence on the development of new trends in acoustics (for example, on the development of nonlinear hydroacoustics, solid-state acoustics, and crystal acoustics), as well as on the development of the general theory of nonlinear waves.

The Division of Experimental and Theoretical Physics has recorded major scientific advances during the recent period from 1953 to 1979.

For the development of a new method in quantum field theory and statistical physics, which, among other things, led to confirmation of the theories of superfluidity and superconductivity, Academician N. N. Bogolyubov was awarded a Lenin Prize in 1958. Bogolyubov's series of studies is an important achievement of the Soviet theoretical physics school.

In 1966, Academician A. N. Tikhonov, head of the mathematics chair, was awarded a Lenin Prize for a cycle of studies of "incorrect" problems; in recent years, this area has been advanced greatly both by Tikhonov himself and by his students (Tikhonov is now head of the Moscow State University Department of Computer Mathematics and Cybernetics) and is of great practical importance.

As we noted earlier, a 1970 Lenin Prize for research in plasma physics went to A. A. Vlasov, professor of the theoretical physics chair. A Lomonosov Prize was awarded in 1971 to A. A. Sokolov, F. A. Korolev, I. M. Ternov, and O. F. Kulikov for new investigations of synchrotron radiation and its uses.

Sokolov and Ternov (at the time professor of the theoretical physics chair) conducted a series of studies of the spin self-polarization of ultrarelativistic electrons and positrons (a discovery registered in 1973, for which a USSR State Prize was awarded in 1976).

In a joint effort by the mathematics chair and the Moscow State University Scientific Research Computer Center, general methods were formulated for calculation of radiating systems of various types on the basis of a fundamentally new formulation of the problem of mathematical design of electrodynamic systems. These methods were used to solve several applied problems (USSR State Prize 1976; Academician A. N. Tikhonov, Prof. A. G. Sveshnikov, *et al.*).

Professor V. F. Kiselev obtained important results from study of phenomena on the surfaces of semiconductors. Professor L. V. Levshin investigated intermolecular and intramolecular interactions by luminescence methods.

Note should be taken of interesting work done in the Division of Solid State Physics.

Research by K. P. Belov and his students developed the fundamental properties of rare-earth magnetics (metals, alloys, ferrites) and led to the discovery of new phenomena—giant magnetostriction, "orientational" phase transitions, sharp anomalies of magnetothermal and electrical properties, and determination of the enormous energy of magnetic anisotropy and magnetoelastic energy.

The data obtained here provided the physical groundwork of a deliberate search for efficient new magnetic materials for electronics and computer engineering (Moscow State University Lomonosov Prize, 1970).

G. S. Krinchik and M. V. Chetkin investigated the Faraday effect in ferrites that are transparent in the visible and infrared. Economical light modulators were designed around these materials. A frequency-independent Faraday effect was discovered, which has made it possible to detect the magnetic susceptibility of ferromagnetics at optical frequencies. The phenomena observed were registered as discovery (1975). The same scientists also discovered and investigated a new surface-magnetism phenomenon and were first to observe new magnetooptical effects—e.g., orientational and polarly and meridionally strong effects. Professor Yu. P. Gaĭdukov and Corresponding Member N. E. Alekseevskiĭ succeeded in detecting various types of asymptotic behavior of the magnetic resistance of metals in strong effective magnetic fields (USSR State Prize, 1967).

The last decade has seen the emergence of a new trend in the Division of Solid State Physics: study of substances under the combined action of high pressures (up to 500 000 atm), strong uniaxial strains (up to 1–2%), strong magnetic fields (intensities up to 1 million oersteds), and alloying at low and ultralow (below 0.1 K) temperatures (Prof. N. B. Brandt and coworkers). Investigation of substances (chiefly semimetals and narrow-band semiconductors) under these conditions resulted in the discovery of several new effects and phenomena. The following have been most important: discovery of the new phenomenon in which dielectrics become metals and vice versa in strong magnetic fields (N. B. Brandt, Moscow State University Lomonosov Prize, 1968) and the discovery of two hitherto unknown states of matter—the gapless state (with zero energy gap in the spectrum) and the exciton phases that had been predicted theoretically by Mott in 1949 but had never been observed (a certificate was issued for the discovery to N. B. Brandt, E. A. Svistova, S. M. Chudinov, and A. A. Abrikosov in 1975).

The aforementioned work on synchrotron radiation, a subject that has been developed broadly worldwide in recent years, is currently being conducted in the Division under the direction of Prof. I. M. Ternov of the quantum theory chair; they embrace a broad range of problems with a bearing on the electromagnetic and gravitational radiation of relativistic particles. Use of this radiation in astrophysics, in investigations of the structure and properties of solids, and in biology is also important. Let us briefly discuss the activity of the Division of Astronomy, the Shternberg State Astronomical Institute (GAISh), and Division of Geophysics during the period 1953–1979.

In the fall of 1966, after the move to the new building in the Lenin Hills, the Astronomy Division was transferred from the Mechanics and Mathematics Department to the Physics Department in view of the drastic astronomical subject matter changes that were contemplated and the need to teach physics to student astronomers. With occupancy of the new GAISh building in the Lenin Hills, a Crimean Observing Station was built and fitted out with new astronomical instruments. The world's largest radio telescope, the RATAN-600, which had been built by the USSR Academy of Sciences in close collaboration with Moscow State University, went into operation in 1978. The GAISh Radio Astronomy Laboratory was set up at the radio telescope site and proceeded with observations. The institute has also acquired a new 1.5-meter reflector for installation at the GAISh mountain observatory now being built in the Kitab District of Uzbekistan. The GAISh has become one of our country's largest astronomical, scientific, and teaching establishments, covering all of the principal scientific areas of modern astronomy. Even during the first postwar decade, the Astronomy Division and the GAISh had obtained important scientific results, including, for example, the pioneering work of Corresponding Member of the USSR Academy of Sciences P. P. Parenago on variable stars and the structure of the Galaxy and the research of Prof. B. V. Kukarkin, who demonstrated that subsystems of stars with different physical and kinematics characteristics exist in the Galaxy.

The launching of the first artificial earth satellite on October 4, 1957 had a great influence on the course taken by astronomy at Moscow State University. The strong GAISh scientific staff, with radioastronomers and celestial mechanicists in the lead, soon found itself at the very center of space research.

The work of the Moscow celestial mechanics school has also been extremely successful. The nonclassical problems that had previously been its bread and butter were now fully appreciated. The Moscow astronomers were indeed prepared for solution of problems in astrodynamics and the analytic theory of the motion of artificial earth satellites under the action of the attraction of the nonspherical earth, atmospheric drag, and the perturbing effects of the moon and sun. Among other things, Prof. G. N. Duboshin elaborated a theory of the translational and rotational motion of natural and artificial celestial bodies and performed fundamental research on analysis of the stability of their motion. Professor E. P. Aksenov developed new and efficient celestial mechanics methods for the case of strongly perturbed motion of celestial bodies. Duboshin, Aksenov, E. A. Grebenikov, and V. G. Demin were awarded a USSR State Prize in 1971 for this series of studies.

The road to cosmic subject matter took an interesting turn for positional astronomy, the original astronomical field of endeavor at the GAISh. From the organization of large-scale observations and photographic tracking of the first satellites in flight, the positional astronomers turned to fundamental problems of space geodesy, which emerged during the 1960s. The development of laser methods for observation of satellites, together with radiointerferometry, has made it possible to improve accuracy in investigation of the earth's rotation by an order of magnitude. A system of highly accurate star-position catalogs is being prepared for the same purpose. An extremely large volume of gravimetric work was done during this period. The GAISh participated in more than 30 expeditions at sea and in the Antartic. Gravimetric charts of the Antartic continent, Australia, and part of the World Ocean were prepared and work was started on ambitious projects: determination of the gravitational constant, mass, and average density of the earth on a new experimental installation and a new theory of automatic measurement of the force of gravity at sea.

In the field of theoretical astrophysics, the research in cosmology that had been started before the war by Academician V. G. Fesenkov and his student A. L. Zel'manov was developed intensively at the GAISh. Zel'manov worked out the mathematical formalism of a theory of the inhomogeneous and anistropic Universe and formed the Soviet school of relativistic cosmology. In 1966, Academician Ya. B. Zel'dovich came to work at the GAISh and soon surrounded himself with a large group of astrophysicists and physicists interested in problems of relativistic astrophysics. The attention of this team was focused on the evolution of the Universe, including its initial stages (the theory of the "hot" Universe, the origin of the Galaxy, energy release in binary systems, including relativistic components—neutron stars, black holes, etc.). The work of Prof. D. Ya. Martynov and his students on close binary stars and the rotation of the line of apsides of Wolf-Rayet stars, etc., also come under theoretical astrophysics. The studies that he began back in 1937 have now emerged at the forefront of theoretical astrophysics with the discovery that such systems evolve very rapidly. Professor S. B. Pikel'ner proposed a unified conception of the heating of interstellar gas by soft cosmic rays and considered the influence of magnetic fields on the structure of the spiral arms and the processes of star formation.

The geophysical research that has become so important during the last decade was developed in the Division of Geophysics in the areas of earth physics (Academician V. A. Magnitskiĭ), atmospheric physics (Academician A. M. Obukhov), and marine physics (Prof. A. M. Gusev). The basic fields of research are study of the structure and processes of the earth's crust and mantle by geophysical methods; ocean bottom structure and seismicity (chair of earth physics); research on the dynamics of the atmosphere, its oscillations and waves, its stability and general circulation, atmospheric turbulence, atmospheric ozone, and flow over mountain obstacles (chair of atmospheric physics); study of the shaping of the World Ocean's thermal and dynamic regime in the process of its interaction with the atmosphere, dynamic and thermal processes in rivers and reservoirs (chair of marine physics).

In recent years, Magnitskiĭ has successfully developed a theory of the vertical motions of the earth's crust, studied their patterns and causes, and investigated the mantle of the earth, an area in which he has recorded pioneering results. Academician Obukhov has done interesting research on the structure of nonlinear systems in hydrodynamic media and the related modeling problems, and Prof. Gusev has worked on the air-sea interaction problem. We should also note that important work is being done in the chair of general physics for the physics department (chair: Prof. A. N. Matveev) to improve the efficiency of teaching methods for the general physics course; scientific work is also being done on the history and methodology of physics under the direction of Prof. B. I. Spasskiĭ and a lecture course on this range of problems has now been taught for some time.

The physical scientists of Moscow University are involved in the development of basic textbookds for use in teaching various subdivisions of physics in the colleges and for physics in the intermediate school. Some of these texts have become classics and are still in use after being studied by more than a generation of physicists: for example, I. E. Tamm's "Theoretical Fundamentals of Electricity," G. S. Landsberg's "Optics," S. É. Khaĭkin's "Mechanics," L. I. Mandel'shtam's "Lectures on the Theory of Oscillations," the "Theory of Oscillations" by A. A. Andronov, S. É. Khaĭkin, and A. A. Vitt; S. P. Strelkov's "Introduction to the Theory of Oscillations," S. G. Kalashnikov's "Electricity," D. I. Blokhintsev's "Quantum Mechanics," the "Quantum Mechanics" of A. A. Sokolov, I. M. Ternov, and Yu. M. Loskutov, "Equations of Mathematical Physics" by A. N. Tikhonov and A. A. Samarskiĭ, "Nuclear Physics", by Yu. M. Shirokov and N. P. Yudin, A. A. Kolomenskiĭ's "Theory of Ring Accelerators," D. Ya. Martynov's "Textbook of Practical Astrophysics," S. N. Blazhko's "Textbook of Practical Astronomy," and many others.

In this brief exposition of the principal scientific results obtained by physical scientists, astronomers, and geophysicists of Moscow University, we have not, of course, treated all of the important investigations by any means. However, the work of which we have taken note makes clear the breadth of the research and its significance for modern physics, astronomy, and geophysics.

Research is now being done in all fields of physics in the Moscow University physics department and at two of its institutes; the department has a student body of over 3000, more than 300 graduate students, about 100 foreign students, and about 80 exchange graduates and students. The department employs more than 100 professors, about 200 docents and senior instructors, more than 130 assistants, 9 Corresponding Members of the USSR Academy of Sciences, and 11 Academicians.

Moscow University has played and will continue to play a major role in the development of physics in our country. The university has broad international scientific connections in the physical sciences. Its graduates—physicists, astronomers, and geophysicists—are at work in the institutes of the USSR Academy of Sciences, the Academies of Sciences of the Union Republics, the branch institutes, universities, and other institutions of higher learning in our country. Many of them have become noted scientists, government officials, professors and instructors, and engineers. It is sufficient to note that between 1917 and the present, 30 out of the 80 physicomathematical scientists who have been elected full members of the USSR Academy of Sciences were graduates of the physicomathematical or, later, the physics department of Moscow State University. Here we name only some of them whose work has been associated or is now associated with Moscow University: A. A. Andronov, S. I. Vavilov, B. A. Vvedenskiĭ, E. P. Velikhov, L. V. Keldysh, G. S. Landsberg, M. A. Leontovich, A. A. Logunov, A. A. Samarskiĭ, A. V. Severnyĭ, I. E. Tamm, A. N. Tikhonov, I. M. Frank, R. V. Khokhlov, and A. V. Shubnikov.

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[1]The period from 1775 to 1917 has been described by B. I. Spasskiĭ, the period from 1917 to 1941 by L. V. Levshin, and time from 1941 to the present by V. A. Krasil'nikov.

Translated by R. W. Bowers