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ALEKSANDR YUL'YEVICH ISHLINSKII (on the 90th anniversary of his birth)†

Aleksandr Yul'yevich Ishlinskii was an outstanding scientist of the twentieth century who carried out basic research in the field of the mechanics of deformable media, rigid-body dynamics, gyroscopy and inertial navigation, having created new areas in the divisions of science to which he devoted his talents as a scientist, engineer, and remarkable teacher.

Ishlinskii was born on 6 August 1913 in Moscow. During the Russo-Japanese War, his father served as a machine quartermaster on the cruiser *Bogatyr'*, and for his part in the Kronshtadt uprising (1906) he was deprived of the nobiliary rank.

In 1931, Ishlinskii began a second course in the Mechanics and Mathematics Faculty of the M. V. Lomonosov Moscow State University. For over 70 years from this point, his life and activity were inseparably linked with the Faculty and the University. Among his teachers were N. N. Bukhgol'ts, V. V. Golubev, M. A. Lavrent'yev, A. P. Minakov, A. I. Nekrasov, M. M. Filonenko-Borodich, A. Ya. Khinchin, and many of the brilliant professors who were at Moscow University at that time. Later he would say: "I owe the greatest personal debt to Moscow University. I happened to study with first-class scientists, take part in scientific seminars, give lectures, conduct practical work, and take great pleasure in the achievements of my students. The spirit of the University lies in the logical sequence of reasoning, the thorough analysis of experimental data, and the peculiar accuracy of formulations and of the thinking process itself, and these have always been for me the guiding factors of my life and activity". Ishlinskii defended his Master's thesis on "Rolling friction" in 1938, and his Doctor's thesis on "The mechanics of incompletely elastic and viscoplastic bodies" in 1943. From 1945 onwards he was a professor at Moscow University.

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Even as a post-graduate student, Ishlinskii was engaged in intense, all-round teaching at the L. B. Krasin Moscow College of Electrical Engineers and at various higher institutes of learning: the M. V. Lomonosov Moscow State University, the N. E. Bauman Moscow Technical High School, the Moscow Power Institute, the Automotive Institute, the K. Liebknecht Pedagogical Institute and the V. V. Kuibyshev Military Engineering Academy, and he headed the Department of Theoretical Mechanics of the Moscow Military Engineering School (1943–1945).

In 1940 he began work in the instrument-making industry. Contact with the remarkable engineer N. N. Ostryakov, with the greatest designers, including S. F. Farmakovskii, and with the eminent Academician A. N. Krylov defined the interest and direction of his research in the field of gyroscopy and precise instrument making.

In 1947, on the invitation of Academician M. A. Lavrent'yev, Ishlinskii moved to Kiev, where he was elected a full member of the Ukrainian Academy of Sciences and made Director of the Institute of Mathematics (IMat) of the Ukrainian Academy of Sciences. Here, under his leadership, new areas of applied research were developed, new departments were set up, including the Department of General Mechanics, and the Kiev school of mechanics was formed – specialists on gyroscopes and inertial navigation systems. He established wide-ranging ties between IMat and instrument-making organizations in Moscow, Leningrad, and Kiev, and took part in full-scale research on navigational instruments at northern latitudes on the island of Franz Joseph Land.

At Kiev University, he ran original courses on plasticity theory, gyroscope theory, the plane problem of the theory of elasticity and the history of mechanics. In 1955, he returned to Moscow but, up to the last days of his life, he retained his fruitful scientific ties with his Kiev colleagues and students.

From 1956 onwards, he headed the Department of Applied Mechanics at Moscow State University, later renamed the Department of Applied Mechanics and Control Processes. In 1959 he become Director of the Institute of Mechanics at Moscow State University. In 1960 he was elected a member of the USSR Academy of Sciences. From 1964 onwards, he was Director of the newly founded Institute for Problems in Mechanics (IPMekh) of the USSR Academy of Sciences (which later became the Institute for Problems in Mechanics of the Russian Academy of Sciences), which he led until 1990. Under his leadership, the Institute became the largest scientific centre in the country in the field of mechanics.

Ishlinskii's creative scientific work was characterized by a breadth and variety of interests: from questions of fundamental importance for theory to specific application problems. In mechanics of solids these were problems of the behaviour of elastic, plastic, viscoplastic, and hereditary media, problems of the static and dynamic failure of bodies and structures, and many other problems.

His research on the theory of rolling resistance was related to the construction of models of relaxing media. He proposed and studied a rolling scheme based on concepts of deformation of the base – earths and other relaxing media. He analysed the position of slip and stick zones during rolling taking account of friction in the slip zone, and he explained jumps in friction. This work served as the basis for numerous other investigations in this field.

Examining the flow and stability of viscoplastic bodies, he chose to use the Eulerian concept of the flow of a medium, which turned out to be a good idealization for describing the flow of rigid-plastic media. He had a premonition about the role of piecewise-smooth loading surfaces and introduced new piecewise-smooth conditions of plasticity – the condition of plasticity of the maximum reduced stress which restricted, along with the condition of the maximum principal shear stress (Tresca's plasticity condition), the class of admissible non-concave plasticity conditions for a perfectly plastic isotropic body. He gave a numerical solution of the problem of determining the limiting load when a smooth punch of spherical shape presses into a perfectly plastic half-space (the Brinell test).

In constructing the general relations of the theory of perfect plasticity, he proceeded from Saint-Venant's statically determinate relations for the plane problem. He formulated relations of the three-dimensional problem of the theory of perfect plasticity for the intersection of two yield surfaces without the hypothesis of proportionality of the stress and strain rate deviators, and thereby obtained relations corresponding to concepts of the generalized associated yield law.

The theory of the translational hardening of plastic material is due to him. On the basis of the mechanical model he proposed, illustrating the effect on hardening through a change in the internal stresses, he derived general relations for the hardening of plastic material, describing the properties of acquired anisotropy, the Bauschinger effect, etc.

The remarkable experiments by M. A. Lavrent'yev, which revealed the formation of different harmonics during the dynamic compression of a tube, served as the basis for research by Lavrent'yev and Ishlinskii into the dynamic stability of elastic and inelastic systems. An analysis of the change in the initial deviations with time was the basis of their work. A cycle of investigations by Ishlinskii was concerned with the study of imperfect elasticity, vibrations, and the failure of solids. He examined problems of rolling and drawing at high strain rates, the motion of sand, the emergence of residual strains when elastoplastic bodies are unloaded, etc.

A fine analysis of the propagation of cracks in an elastic body in the presence of forces of adhesion should be noted. For the case of widening of a rectilinear cut by distributed forces applied normal to its opposite sides, he settled many problems that had previously been the subject of debate.

His first work on gyroscope theory, begun in 1940, was devoted to a study of the geometry and kinematics of gimbals in which practically all gyroscopic systems and devices were installed. To determine various kinds of stabilization error and errors in determining the angular coordinates of remote objects, he used an analytical approach and obtained a number of exact results in the mechanics of finite rotations. The classical theorem of so-called solid angle accumulation, which was the basis for calculating the accuracy of stabilizing different kinds of object, is due to him. He successively and systematically set about explaining the factors affecting the accuracy of gyro devices. In his work, he analysed the effect of the stiffness of structures and the effect of friction and vibrations on the operation of gyro devices. The theory of new gyro devices (air-suspended gyrovertical, multi-rotor attitude-and-heading reference device, directional gyro, a gyroscopic banking leveller), as well as the theory of a gyro pendulum and a directional gyro moving along the Earth sphere were developed. A fine investigation he carried out on estimating the procedural error of a directional gyro moving along the Earth surface was of fundamental importance for solving the problem of autonomous navigation in the North Pole region, where the directional gyro was the only means of indicating the course. He obtained the conditions to be imposed on the parameters of gyro systems and the initial conditions of their motion which ensured that the deviation of gyro devices was independent of the acceleration of the manoeuvring of objects on which these devices were positioned. A development of his work on gyroscope theory was his research on inertial navigation systems.

For a long period of his scientific activity, his attention was drawn to the mechanics of the motion of rapidly rotating rigid bodies. It turned out that processes of this kind can be studied using a string suspension. The experimentally observed diversity of the stable and unstable forms of the dynamic behaviour of an axisymmetric rigid body required much effort for their description. New steady modes of motion of bodies were found. Investigations of the motion of bodies on a string suspension are among the classical investigations in rigid-body dynamics.

He wrote more than 300 scientific papers as well as basic monographs: *The Mechanics of Special Gyro Systems* (1952), *The Mechanics of Gyro Systems* (1963), *Inertial Control of Ballistic Missiles* (1968), *Orientation, Gyroscopes, and Inertial Navigation* (1976), *The Mechanics of Relative Motion and Inertial Forces* (1981), *Applied Problems in Mechanics* in two volumes (1986), *Classical Mechanics and Inertial Forces* (1987), *Rotation of a Rigid Body on a String and Related Problems* (1991, together with V. A. Storozhenko and M. Ye. Temchenko), *The Mathematical Theory of Plasticity* (2001, together with D. D. Ivlev), and *Stability Analysis of Complex Mechanical Systems* (2002, together with V. A. Storozhenko and M. Ye. Temchenko), in which the most complex problems of mechanics were set out. Each new generation of young researchers, engineers, and scientists studies and continues to study these.

In his creative work, he frequently turned to the history and methodology of mechanics, and to interpreting its achievements. He wrote the book *Mechanics: Ideas, Problems, and Applications* (1985). The range of problems considered in this book is very varied: the historical development of mechanics and reflections on its achievements, on unsolved problems and on the place of mechanics among other natural sciences. He brought a deep insight into the essence of the phenomena under discussion, and attempted to provide a complete and objective history of a problem. The book contains a remarkable essay about Galileo Galilei and reminiscences on deceased contemporaries, written with a profound respect for the individuals and their scientific achievements.

In 1965 he was appointed Chairman of the Scientific Procedural Council for Theoretical Mechanics at the Ministry of Higher and Special Secondary Education of the USSR. He always defended the role and importance of theoretical mechanics as a basic discipline and prevented attempts to exclude it from college curricula.

He carried out a vast amount of publishing work. He was Editor-in-Chief of the journal *Izvestiya Ross. Akad. Nauk. Mekhanika Tverdogo Tela*, Editor-in-Chief of a number of periodicals and other publications, and a member of the editorial board of many journals.

His scientific, organizational, pedagogical, and social activity was highly valued by his country. He was given the title of Hero of Socialist Labour, and awarded three Orders of Lenin, an Order of the October Revolution, two Orders of the Red Banner of Labour, two Orders of the Friendship of Nations, the order of the "Badge of Honour", a first-degree Order of Cyril and Methodius, and many medals.

He was a winner of the Lenin Prize (1960), the State Prize of the USSR (1981), the State Prize of the Russian Federation (1996), the N. N. Ostryakov Prize (1975), the A. N. Dinnik Prize (1981), and the V. G. Shukhov Gold Medal (1992), and he was awarded many other named prizes and medals by different international academies and scientific societies.

He was the first President of the All-Union Council of Scientific and Engineering Societies, Honorary President of the Russian Engineering Academy, President of the International Federation of Engineering Organizations, and Vice-President of the International Federation of Scientists. He was a foreign member of the Academies of Science of Poland and the Czech Republic, and of engineering societies in Great Britain and Mexico.

His permanent creative participation in the development of central areas of science and engineering, his clear and distinct formulation of problems, his brilliant presentation of material, his know-how to obtain clear, up-to-date results, so necessary for engineering practice, and his personal charm, sensitivity, and *joie de vivre* attracted young people seeking new ideas and wishing to apply their creative efforts. His students and successors are still using and developing his ideas, and applying the results he obtained in the planning, design, and manufacture of different kinds of mechanical devices and systems. Many of his students have become great scientists.

He had a sharpness of mind, competence, correctness and benevolence. He possessed an exceptionally powerful intellect and a staggering scientific intuition. His judgements were deeply thought out, and his assessment of events and people was sober and balanced. He himself defined his place in the world and his attitude to life as follows: "A scientist is not a politician, he must get on with his own affairs and influence the surrounding world, in the main, using the laws of nature that he has discovered. He then places less onus on society and more upon himself".

With his passing an entire epoch has gone, the epoch of M. V. Keldysh and M. A. Lavrent'yev, of S. P. Korolev and V. I. Kuznetsov. He has left a lasting mark on science, and his achievements have entered the golden treasury of mechanics.

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1926

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