Physics – Uspekhi **53** (1) 101 – 102 (2010)

PERSONALIA

PACS number: **01.60.+q**

Vitalii Dmitrievich Shafranov (on his 80th birthday)

DOI: 10.3367/UFNe.0180.201001i.0107

Academician Vitalii Dmitrievich Shafranov — an outstanding physicist and one of the founders of the modern theory of high-temperature plasmas and controlled thermonuclear fusion — celebrated his 80th birthday on 1 December 2009. V D Shafranov's work built the foundations of the theory of confinement, equilibrium, and stability of plasmas in toroidal magnetic systems, including widely known 'tokamaks'.

V D Shafranov was born in 1929 in the village Mordvinovo of the Ukholovo district of the Ryazan region. His father, Dmitrii Matveevich Shafranov, was an engineer who built roads, and his mother, Faina Dmitrievna Shafranova, was a teacher. V D Shafranov attended primary school in Chashnikovo village, then another in Kryukovo village of the Moscow region. In 1941, the family lived for several days under German occupation but miraculously escaped. During the difficult war years, Vitalii Shafranov attended school and worked together with his father on road construction. At 14 years of age he received his first mark of distinction from the State: certificate No. 442 of the Main Directorate of Highway Construction of the USSR Ministry of Internal Affairs (NKVD) "for earlier-than-planned completion of work in 1943." In 1946, V D Shafranov graduated cum laude (with Gold Medal distinction) from high school in Smolensk. After graduating in 1951 from the Physics Department of Moscow State University (the Chair of the Structure of Matter), V D Shafranov began working at the Theoretical Department headed by Academician Mikhail Aleksandrovich Leontovich at LIPAN (Laboratory of Measuring Instruments of the USSR Academy of Sciences) as today's Russian Research Centre 'Kurchatov Institute' was known at the time.

V D Shafranov's first research paper, "On the stability of flexible wire in a longitudinal magnetic field", was the result of a collaboration with M A Leontovich in 1952. This work formed the launching pad for subsequent studies into the stability of plasmas in a magnetic field. Several years later, at the Fourth International Conference on Ionization Phenomena in Gases (Venice, 1957), V D Shafranov delivered a talk, "On the equilibrium of magnetohydrodynamic configurations", which immediately rocketed him into the international cohort of the leading thermonuclear fusion scientists: he derived the general equation of the plasma equilibrium in an axisymmetrical magnetic field.

Among V D Shafranov's numerous achievements in science, one needs to specially emphasize three pioneering results which rightfully bear his name and without which neither plasma theory nor experimental work could have become what they are in any country dealing with controlled thermonuclear fusion.

The first one is the above-mentioned equation of plasma equilibrium in an axisymmetrical magnetic field (derived by V D Shafranov in 1956 and published in 1957), better known in the scientific literature as the Grad–Shafranov equation. [1] This second-order differential equation relates the shape of the cross section of the magnetic surfaces to the shape of the pressure profile in the plasma and that of the current flowing through it.

Vitalii Dmitrievich Shafranov

Every tokamak in the world, including the largest in the world — ITER (International Thermonuclear Experimental Reactor), now under construction in France — has been designed and built on the basis of this equation; it is successfully applied in astrophysics, hydrodynamics, meteorology, radiophysics, etc.

Another relatively simple equation familiar to many plasma physicists links the displacement of magnetic surfaces with respect to the magnetic axis to plasma pressure and internal inductance of the plasma column. This 'Grad–Shafranov displacement' is perhaps the very first concept that students encounter as they begin to study plasma physics in tokamaks.

[1] Notice that H Grad's paper deriving a similar equation appeared in 1958.

Uspekhi Fizicheskikh Nauk **180** (1) 107 – 108 (2010)
DOI: 10.3367/UFNr.0180.201001i.0107
Translated by V I Kisin

Finally, the third pioneering result (achieved in 1953) is the Shafranov–Kruskal criterion defining the limit of stability of current-carrying plasma under screw perturbations. It was perfectly justified that at the defense of Shafranov's CandSc thesis (PhD) in 1958 the council decided to confer on Vitalii Dmitrievich the degree of Doctor of Science in Physics and Mathematics.

V D Shafranov's professional life is inseparable from the Kurchatov Institute, where he rose all the way from Senior Technician to Chief Researcher. Continuing the work started by M A Leontovich, Vitalii Dmitrievich led for more than twenty years the Division of Plasma Theory of the Institute and headed one of the leading scientific schools in this country — the Leontovich–Shafranov school.

In 1981, V D Shafranov was elected Corresponding Member of the Russian Academy of Sciences (RAS), and in 1997 became a Full Member (Academician) of the Academy.

The list of V D Shafranov's awards and distinctions includes the USSR State Prize (1971) and the Lenin Prize (1984), the Alfvén Prize and the Gold Medal of the European Physical Society (2001), and the Honoris Causa of the Japan Society for the Promotion of Science (2001).

Vitalii Dmitrievich's range of scientific interests is not limited to the theory of plasma equilibrium and stability. Among other things, he carried out profound research into the propagation of electromagnetic waves in plasmas and wrote one of the groundbreaking papers on the structure of shock waves in plasma. Among the more than two hundred of V D Shafranov's research papers, one needs to single out a number of fundamental review papers in the brilliant series *Reviews of Plasma Physics*, whose issues became desktop fixtures for several generations of physicists in this country and abroad. V D Shafranov invariably paid meticulous attention to work on the texts of scientific publications. In writing his own papers, he has always used simple and clear language.

For more than a quarter of a century, V D Shafranov has occupied the position of Editor-in-Chief of the journal *Fizika Plazmy* (Plasma Physics Reports), and since 1980 has been Editor of the *Plasma Physics. Summary of Science and Engineering* series. Under his editorial supervision, a series *Reviews of Plasma Physics* (its 24th volume appeared in 2008) continues in English the multivolume publication in Russian of *Voprosy Teorii Plazmy*; K Miamoto's textbook *Fundamentals of Plasma Physics and Controlled Fusion* has been translated into Russian (2007).

The publication in 2003 and 2005 of the memoirs about the founder of the Russian school of plasma theory, the outstanding theoretical physicist M A Leontovich, which was timed to coincide with the 100th anniversary of his birth, was an important occasion. V D Shafranov, a devoted pupil and worthy successor of Mikhail Aleksandrovich, chaired the editorial board and specially mentioned his kindness, his lofty moral qualities and brave civil position, and his complete rejection of administrative despotism, careerism, and injustice. These human qualities, so rare in our times, distinguish Vitalii Dmitrievich himself. He is extremely modest, always attentive to people's needs, and unpretentious when talking to people.

The recent publication of his book *Unscientific Works* (2009) was a great gift to all colleagues and relatives of Vitalii Dmitrievich — it is a collection of wonderful poetry. The poems are devoted to his friends and closest relatives, to grownups and children, and of course to controlled fusion — his life-work, and reflect another facet of V D Shafranov's talent — his poetic touch. To quote V I Kogan, V D Shafranov's friend and comrade-in-arms:

"Brilliant physicist and splendid poet — What a happy combination!"

From the bottom of our hearts, we wish Vitalii Dmitrievich good health, prosperity, and new enviable achievements!

E A Azizov, E P Velikhov, L E Zakharov,
V I Ilgisonis, V S Imshennik, M Yu Isaev,
L M Kovrizhnykh, V I Kogan, S V Mirnov,
K A Razumova, V P Smirnov, V S Strelkov