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PERSONALIA

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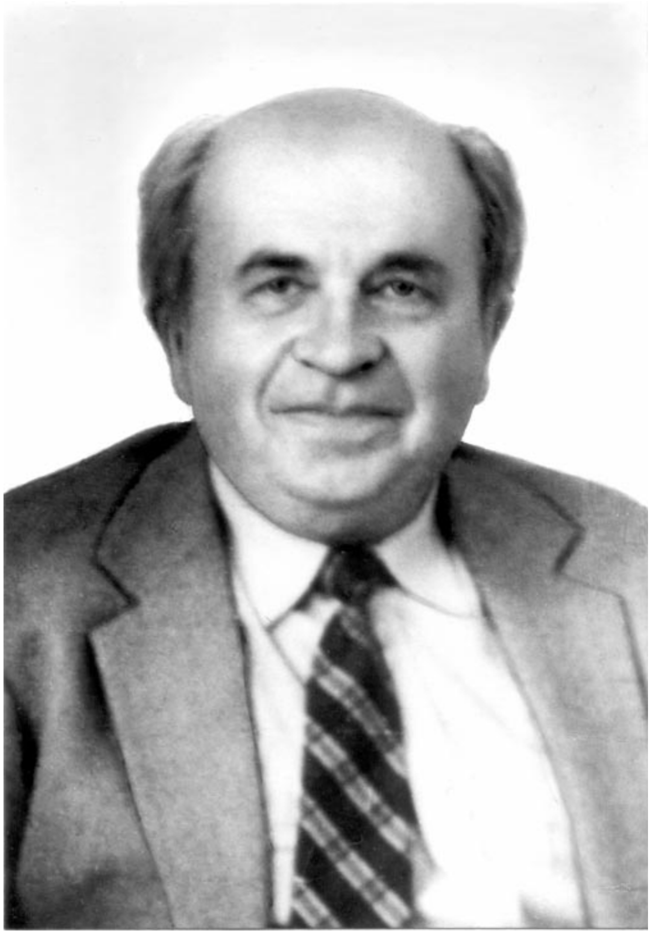
In memory of Boris Borisovich Kadomtsev



Boris Borisovich Kadomtsev
(09.11.1928 – 19.08.1998)

Academician Boris Borisovich Kadomtsev left us on 19th August; he would have turned 70 on 9th November — an outstanding theoretical physicist, teacher, enlightener, and eminent researcher in plasma physics and controlled fusion.

Born to a family of teachers, he spent his early years in the city of Penza. Even as a boy, he was fond of physics and chemistry experiments, making things with his own hands. In 1946 he entered the department of physics of the M V Lomonosov Moscow State University. For four years after graduation he worked at the Physico-Technical Institute in Obninsk near Moscow, making calculations for the thermonuclear weapons development project, and then joined the Department of Plasma theory (headed by L A Artsimovich) in academician M A Leontovich's theoretical sector at the Kurchatov Institute.

This was the beginning of more than forty years of fruitful engagement in the problem of controlled thermonuclear fusion. In his very first assignment at the Kurchatov Institute, Boris Borisovich devised a new method and quickly solved the problem of distinguishing between the effective and the mean electric field in a plasma both in the absence and presence of a magnetic field, which perplexed theoreticians at the time. After that, he performed an exhaustive study of the local instability of interchange (flute) perturbations of plasma confined in a magnetic field with closed magnetic lines of force.

At that time there was no agreement whatsoever between the theory of magnetic confinement and experiment: in defiance of the idealized theoretical models of a calm inhomogeneous plasma in a magnetic field, real plasma always exhibited strong oscillations. It was difficult even to imagine how one could approach this fervid substance with explanations. It was then that the extraordinary physical intuition and imaginative thinking of B B Kadomtsev came to the fore. Very important for the theory of plasma confinement in a magnetic field in the early 1960s were the explanations given by B B Kadomtsev to the Lennert and Hu experiments on plasma instability in a glow discharge placed in an external magnetic field (current convection instability), and to the experiments of M S Ioffe and colleagues concerned with detection of trough instability and the resulting loss of plasma. These two works by B B Kadomtsev became milestones in the theory of controlled fusion, since they refuted the prevailing belief in the universality and inevitability of Bohm diffusion that shattered the hopes for a feasible thermonuclear reactor. B B Kadomtsev's works instilled faith in the possibility of gaining control over the processes in plasma. In those years he also performed studies of the mechanisms for a self-sustaining longitudinal magnetic flux in a toroidal pinch stabilized with a weak magnetic field (in the large British toroidal installation ZETA famous from 1958 – 1968). As a matter of fact, these were the first steps in the explanation of the self-organization of a highly nonequilibrium plasma continuously pumped with energy.

In the early 1960s B B Kadomtsev was preoccupied with the highly advanced theoretical problem of plasma turbulence in a magnetic field. Together with his pupil V I Petviashvili, he derived the kinetic equation for describing wave scattering by particles in the case of weak turbulence. Later he completed a comprehensive cycle of theoretical studies of collective phenomena in high-temperature plasma, summarized in his monograph entitled *Plasma Turbulence* and published in Russian in the "Problems of Plasma Theory" book series, and in English as a separate book by Academic Press in 1965. These publications earned him a name as the leading specialist in collective phenomena — an important new branch of physics.

Later on, B B Kadomtsev concentrated on the physics of plasma in toroidal systems — tokamaks. Widely known is his analysis (jointly with O P Pogutse), published in 1967 in the "Problems of Plasma Theory" series, and in English in *Reviews of Plasma Physics*, Vol. 5 (Plenum Press, 1970), and concerned with the broad class of possible plasma instabilities in tokamaks: hydromagnetic, local and global corkscrew, slower drift and dissipative instabilities on trapped particles. Also evaluated was the effect of all these instabilities on heat and mass transfer processes. On the basis of these results, in 1967 B B Kadomtsev ascertained the technical feasibility of a tokamak-based thermo-

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nuclear reactor. This conclusion persuaded Academician L A Artsimovich, who was in charge of the Soviet program of controlled fusion, to step up the experimental studies with tokamaks, which very soon led to worldwide acknowledgment of these systems for magnetic confinement of plasma. This period was also marked with the derivation of the well-known Kadomtsev – Petviashvili equation — a two-dimensional integrable nonlinear equation for ion-sonic waves.

Along with intensive research in the physics of high-temperature plasma, B B Kadomtsev never lost interest in the general problems of theoretical physics. In 1957, for example, he formulated the theory of fluctuations of the distribution function in the Boltzmann equation. Later, in connection with the discovery of pulsars, he performed an interesting series of studies concerned with the properties of matter in a superstrong magnetic field. About ten years ago he put forward an interesting theory of ball lightning as a gas accumulator in which the electric and magnetic fields are generated in a self-consistent way. More recently, in connection with the experimental production of Bose – Einstein condensate, Boris Borisovich gave a new transparent analysis of the physics behind this fundamental phenomenon. From his university years he nourished the idea of explaining the wave properties of microscopic objects as a result of their interaction with external macroscopic objects, and with keen attention he followed the new developments in the fundamentals and interpretations of quantum mechanics.

Continuing his original research aimed at explaining the anomalous phenomena in the tokamak plasma (which led to the formulation of his fundamental theory of internal disruptions in tokamak, the similarity theory for transport processes in plasma in magnetic field, and the theory of self-organization of tokamak plasma), Boris Borisovich became actively engaged in the organization of science. Since 1973, after the demise of L A Artsimovich, B B Kadomtsev stood at the head of the Department of Plasma Physics in the Kurchatov Institute for Atomic Energy (now the Institute of Nuclear Fusion of the Russian Research Center 'Kurchatov Institute'). In 1976 he becomes the Editor-in-Chief of the *Soviet Physics – Uspekhi* journal. He also chaired the Joint Scientific Council of the Russian Academy of Sciences on the Problems of Plasma Physics, and was in charge of scientific research in the framework of the international thermonuclear experimental reactor project (ITER).

Holding the chair of plasma physics and chemistry at the Moscow Physico-Technical Institute, B B Kadomtsev devoted much time to working with students. A course that he taught to the students of the department of physical and molecular chemistry in 1976 formed the basis of the book entitled *Collective Phenomena in Plasma* (Moscow: Nauka, 1976), which offers a comprehensive and lively account of contemporary plasma physics. The "Institute of Physics Publishing" issued his book *Tokamak Plasma: A Complex Physical System*.

Quite recently, in November 1997, B B Kadomtsev finished a new book entitled *Dynamics and Information*. This philosophical and deeply conceptual book is addressed to students, postgraduates, researchers interested in the fundamental problems of physics, and is devoted to the most important aspects of the physics of complex systems. The behavior of such systems in classical physics is characterized by the phenomenon of dynamic chaos, on account of which even the slightest external perturbations grow exponentially fast within the system. Because of this, the characteristics of the system exhibit a substantial dependence on the state of the environment. Even a small external force may cause transition of the system to a new possible state if there are points of bifurcation. Such a transition may be interpreted as the result of a signal (information) received by the system from its environment. In complex systems, the information aspect of its behavior becomes more important, and plays a decisive role in the quantum mechanical treatment. In his book B B Kadomtsev places special emphasis on the fact that the wave function carries information — in fact, the wave function describes the 'field of possibilities' that are realized after the measurement. The measurement is then an actually irreversible process which secures one possible outcome and eliminates all other possibilities. This results in the collapse of the wave function, which must therefore be described in the case of irreversible processes by the generalized Schrödinger equation with a random operator (which is the quantum mechanical counterpart of the classical Langevin equation). Using a simple example of an open quantum system — a heavy particle diffusing in a gas — he shows how the scattering of this particle by the gas atoms leads to the collapse of the wave function, and how the sequence of collapses leads to the generalized Schrödinger equation (with a complex Hamiltonian) which describes collapses, or the decoherence of the open system under the impact of its environment. This is a natural transition from quantum to classical mechanics, which does not require the introduction of a sophisticated concept of the world with Einsteinian 'hidden parameters', in a sense detailing Bohr's idea of the fundamentality of randomness in quantum mechanics. These concepts were applied by B B Kadomtsev to explain the unexpected experimental findings of Yu L Sokolov: the coherent addition of 2P amplitude in the excited 2S hydrogen atom passing near a metallic surface. Written in the lively style of free discussion, this book by B B Kadomtsev will certainly help the reader to get acquainted with the fundamental issues of contemporary physics.

An important occupation of B B Kadomtsev was his participation in the international scientific cooperation on the problem of controlled thermonuclear fusion. He was a member of the Coordination committee for Russian – US cooperation on controlled fusion, the first chairman of the International scientific and technological consultative committee for the international thermonuclear reactor project (ITER), developed under the auspices of the International Atomic Energy Agency (IAEA). He was elected to the Swedish Royal Academy, to Academia Europaea, and received an doctorate from Humboldt University (Germany).

B B Kadomtsev is a laureate of honorary State (1970) and Lenin (1984) Prizes, a recipient of the Order of the Red Banner of Labor and of many medals. He is also the laureate of prestigious international awards for accomplishments in science: the Fusion Power Associates Award, and the Annual Maxwell Award of the American Physical Society (1998).

Boris Borisovich Kadomtsev was a very good-natured and tactful person. Quoting from one of the obituaries (Fusion Power Associates Executive Newsletter, September 1998, Vol. 20, No. 9), "Boris was well known to fusion scientists throughout the world, not only for his key scientific contributions but also for his warm, outgoing personality and engaging human qualities. He was a man whom it was impossible not to love". And so indeed he was. It is especially sad that he has left us at the meridian of his scientific career.

When such people leave us, the world is no longer what it used to be.

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A M Dykhne, L V Keldysh, Yu L Klimontovich,
V I Kogan, M B Menskiĭ, L P Pitaevskiĭ,
V E Fortov, N A Chernoplekov, V D Shafranov