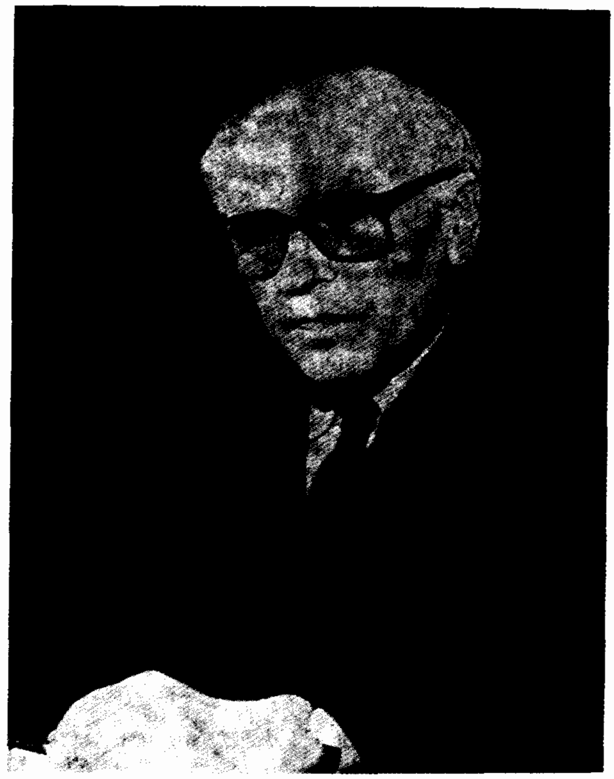
Andreĭ Dmitrievich Sakharov (Obituary)

Scientists of the I. E. Tamm Department of Theoretical Physics at the Physics Institute of the Academy of Sciences of the USSR
Usp. Fiz. Nauk **160**, 163–166 (June 1990)

The death of Andreĭ Dmitrievich Sakharov was a national calamity. Our people, no matter how diverse, were united in the pain. Churches, both Russian Orthodox and Catholic, held memorial services throughout the country, even though he was not a religious man. Although he had long struggled against the coercion of the "organs of law and order", the police and military detachments that controlled the flow of hundreds of thousands by his coffin before the burial and during the funeral procession, and then kept order at the meeting that followed–from the ordinary policemen and soldiers to the generals–comported themselves with the greatest care and tact. He was a sworn enemy of nationalistic strife and yet many of those following his coffin were of the opposite persuasion. Intellectuals and workers, those who had held him in the highest esteem and were now overcome with grief, turned out in multitudes. This did not happen because the various strata of our society were "appropriating" his death, but rather because he stood for universal values, for the wakening emotions that may only be latent or even entirely concealed in our souls, but are nonetheless essential to us all. His very death shook us and lifted our souls another step. Perhaps nobody else ever had more right to Pushkin's words that were engraved on his tombstone: "And long will my people recall me for this ..."

In addition to the pride that he belonged to our community (and that we can understand the side of his life that is hidden from the millions who knew him for his humanity, courage, and struggle without violence), we the physicists are entrusted with the honorable albeit sad privilege of recalling his scientific accomplishments at the gravesite. This is a sad privilege because we realize how much more he could have done in physics, had be not given of himself so freely to humanity. It is sadder still, because science appeared to bring him more immediate joy than any of his other endeavors. The story of his life is now common knowledge. A flood of essays, reminiscences, biographical sketches of his personality and his work has appeared in the press. We need not return to his biography, but let us remember him as a physicist.

There is no doubt that Andreĭ Dmitrievich decided to become a physicist under the influence of his father, Dimitriĭ Ivanovich Sakharov, who had lectured on physics and authored several books, including an excellent collection of university-level physics problems, textbooks, and several popular science accounts. The research of A. D. Sakharov can be clearly divided into three areas, both thematically and chronologically.



ANDREĬ DMITRIEVICH SAKHAROV
(MAY 21, 1921–DEC. 14, 1989)

The first, preliminary as it were, period covered the time between his graduation from the physics department of Moscow State University in 1942 (which he completed in Ashkhabad during the wartime evacuation) and his defense of the Candidate of Sciences dissertation. After graduation he worked in a military production plant on the Volga (from 1942 until the beginning of 1945) where he contributed four inventions related to production control (one of which was patented). There he also completed four small research projects despite his complete separation from the physics community (these were not published and remain to be found). In one of these, perhaps upon learing of the pioneering work by Ya. B. Zel'dovich and Yu. B. Khariton on the chain reaction in uranium, he surmised that in a nuclear reactor the uranium should not be mixed uniformly with the moderator but rather stored in rods (to reduce resonant absorption in uranium). This important principle had already been known

 0038-5670/90/060488-03$01.00

at the time, but only as classified information. Sakharov sent the results of his research to I. E. Tamm and from January of 1945 onwards he became Tamm's graduate student at the Department of Theoretical Physics at the Physics Institute of the Academy of Sciences of the USSR (known by its Russian acronym FIAN). There, in the course of two years, he completed and published three papers: on the generation of high-energy pions, on the optical determination of the temperature of hot plasma, and on 0–0 transitions in nuclei. The latter comprised his dissertation research, but he defended his dissertation almost a year behind schedule because he failed the required examination in Marxism-Leninism. (This proved a heavy blow as he was living in very difficult and hungry conditions with his unemployed wife and newborn child. They were renting a room far from the center of town and the times were generally hard; a Candidate of Sciences degree would have done much to improve their living standards. There is no reason to believe his failure had been politically motivated, since up until the mid-1950's Sakharov's political orientation was thoroughly loyal. His examiners simply could not follow his nonstandard train of thought.) All three papers were quite valuable, especially the experiment-oriented dissertation topic. But for the future great physicist Sakharov they were simply a "warm-up".

Sakharov joined the group created in the Department at the request of I. V. Kurchatov for the purpose of studying the feasibility of thermonuclear weapons. This proved to be the beginning of the second period in his scientific career. Early on he proposed an important innovation which, together with an idea due to another member of the group, advanced the research to the practically promising stage. Sakharov and Tamm were transferred to a secret facility outside Moscow, where A. D. Sakharov worked until 1968 (Tamm returned to FIAN in 1953). He devoted almost twenty years of his life, usually the most productive years of a theoretical physicist, to research that he then (and subsequently) considered necessary for the maintenance of world peace. But his work was not restricted to the grandiose and spectacularly successful program aimed at constructing the hydrogen bomb, on which many outstanding physicists worked together with Sakharov, although according to the general consensus he played a well-nigh leading role. In 1950 Sakharov and Tamm proposed a design of a magnetic thermonuclear reactor and carried out the first, fairly detailed theoretical calculations. This design later evolved into the Tokamak that even today provides one of the main directions towards controlled thermonuclear fusion. Earlier still, Sakharov proposed cold fusion–μ-catalysis–as yet another means to the same end. Recently an expert commission in the U.S. concluded that after the advances of the intervening years this direction appears as promising as the traditional methods. Finally, A. D. Sakharov also proposed laser-driven fusion in an unpublished talk in the early 1960's. At the same time he also invented a method of obtaining ultrahigh magnetic fields known as "magnetic cumulation" (an explosion of a chemical or "nuclear" shell compresses by implosion the field inside a cylinder). His experimental collaborators employed this technique to achieve fields of 16 (in some experiments up to 25) millions of gauss, that is 50–100 times higher than the record of P. L. Kapitsa.

The early 1960's marked the beginning of the third period, as A. D. Sakharov returned to field theory, particle physics, and cosmology. He quickly overcame his accumulated lag and caught up with the recent advances in these fields. Sakharov began attending FIAN seminars more frequently and returned officially to the Department of Theoretical Physics at FIAN in 1969 after being dismissed from the secret facility for his first political "manifesto".

Already in 1965 he published a paper in which the formation of inhomogeneities in the Universe was attributed to quantum fluctuations, soon to be followed by even more radical propositions. In 1966 Sakharov advanced a hypothesis of baryon decay leading to lepton formation. The violation of CP-symmetry made the antibaryon lifetime shorter than the baryon lifetime and thus, given a sufficiently rapid expansion of the Universe, the antibaryons would not survive to our day (he published a more detailed study in 1979). Although this idea originally appeared absolutely implausible, the development of unified field theory (including strong interactions) 12 years later lent credence to a modified version of Sakharov's proposal. The resulting experimental search for proton decay became known as the "experiment of the century". Although the search has not been successful to date, the idea gained such wide acceptance in the physics community that many specialists preferred to abandon that particular version of unified field theory before they let go of the very idea of proton decay.

At the same time A. D. Sakharov advanced an explanation for the appearance of a gravitational field as a result of quantum vacuum fluctuations ("zero-field Lagrangian theory", subsequently expanded in a large 1975 paper). This idea was taken up by other theorists and became known as induced gravitation. In 1970 Sakharov proposed a peculiar "multi-leaf" Universe. A similarly fantastical idea of his was the "reversal of the time arrow" (1980). He suggested that one can choose a point in a pulsating Universe where during both the expansion and contraction in cosmological time, the thermodynamic time increases with distance from the point (i.e., contraction in cosmological time actually manifests itself as expansion in thermodynamic time). The solution then becomes CPT-invariant. The startling character of this hypothesis is undeniable. In 1984, already in internal exile, Sakharov completed yet another important piece of research. In contrast to the usual metric signature (one-dimensional time plus three spatial dimensions) Sakharov proposed the existence of arbitrary signatures with arbitrary numbers of dimensions (the excess dimensions are compacted). For example, different regions of the Universe can exhibit different signatures and metrics; "metric phase transitions" become possible because of quantum tunneling (these ideas of Sakharov complemented the simultaneous works of J. Hartlee, S. Hawking, and A. Vilenkin on quantum cosmology). In parallel with his cosmological studies, in 1967 and the 1970's Sakharov published four papers (one coauthored with Ya. B. Zel'dovich) in which he obtained a semiempirical formula of baryon and meson masses. In 1980 he included this result in the list of six major research fields that he considered most significant in his career (thermonuclear, μ-catalysis, magnetic cumulation, induced gravitation, baryon symmetry, and the mass formula). We should also note that in the very last year of his life Andreĭ Dmitrievich gave a talk at an international seismology conference in which he proposed the idea of defusing earthquakes by subterranean nuclear explosions that would remove the accumulated stresses in deep-lying strata.

Our picture of Sakharov's scientific accomplishments would remain incomplete if we did not mention what he called "amateur problems". These were absolutely specific problems drawn from a staggering variety of topics–from number theory to the cabbage problem he hit upon while helping his wife in the kitchen. Cutting a cabbage produces polygons of various shapes and sizes; Andreĭ Dmitrievich found that the mean number of vertices is four while the ratio of the perimeter squared to the area equals 4π, like in a circle. His 1980 list of most significant achievements was included in his collected scientific works (A. D. Sakharov, *Collected Scientific Works*, Eds. D. ter Haar, D. V. Chudnovsky, and G. V. Chudnovsky, Marcel Dekker, N. Y., 1982) with commentaries by Sakharov himself and many outstanding theorists. But the solutions of his "amateur problems" were not given, even though the cabbage problem indicates how nontrivial they could be. For Andreĭ Dmitrievich they were a relaxing pastime, like chess for others.

In Sakharov's major works one is struck by unfettered imagination, stunning intuition (obvious to all who had ever worked with him), mastery of the theoretical background (there was a case when he reinvented a numerical technique during a computation, unaware that the original author of the technique had spent years on its development), depth and freedom of thought. We should also point out another, possibly accidental trait. With the exception of the mass formula, the themes of his research all pointed to the grandiose: evolution of the Universe; energy release on a grand scale (thermonuclear, μ-catalysis); extremal magnetic fields; in yet another, 1966 paper not mentioned above, Sakharov obtained the maximum possible temperature ($1.42\cdot 10^{32}$ degrees). His style of thought, method of argumentation and choice of research topics all suggested that he was an exceptional, outstanding, let us not be afraid of the word–great, man.

Translated by A. Zaslavsky