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Recommended Citation

Rezgui, H. "In Memory of Professor Andrei Nikolaievitch Tikhonov (1906-1993) on the 25th Anniversary of His Death," *Journal of Humanistic Mathematics*, Volume 8 Issue 1 (January 2018), pages 332-349. DOI: 10.5642/jhumath.201801.16 . Available at: <https://scholarship.claremont.edu/jhm/vol8/iss1/16>

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JHM is an open access bi-annual journal sponsored by the Claremont Center for the Mathematical

Sciences and published by the Claremont Colleges Library | ISSN 2159-8118 | <http://scholarship.claremont.edu/jhm/>

In Memory of Professor Andrei Nikolaïevitch Tikhonov
(1906–1993)
on the 25th Anniversary of His Death

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Synopsis

Thursday, November 8, 2018, is the twenty-fifth anniversary of the death of the celebrated Professor A. N. Tikhonov, one of my most favorite mathematicians. The idea of writing this paper to honor his life and scientific activities came to me as I was reading many of his works; I was impressed by his knowledge, amazing research, profound scholarship, perspicuity and eloquence of expression, painstaking accuracy, and big ideas. My aim is to be clear and evocative, for in this way I feel more in touch with my subject that is very interesting.

1. Introduction

In the 20th century, many mathematicians around the world made positive contributions to our world and to diverse subjects. Among them was Andrei Nikolaïevitch Tikhonov, a groundbreaking, outstanding mind, who has always been involved in the training of able scientists and specialists.

Thursday, November 8, 2018, is the twenty-fifth anniversary of the death of this celebrated, valued, accomplished, and highly respected mathematician and physicist of international renown, a sharp mind, an academician of the Russian Academy of Sciences, a laureate of the Lenin and State Prizes of the USSR, a cognitive and legendary figure, a vital brilliant organizer and leader of science. Professor A. N. Tikhonov is one of my most favorite mathematicians.



Figure 1: Memorial board of A. N. Tikhonov on the Moscow State University (MSU) Second Humanities Building where the Faculty of Computational Mathematics and Cybernetics is located [26].

The idea of writing this paper to honor the life and scientific activities of A. N. Tikhonov came to me when I read many of his works and I was impressed by his knowledge, amazing research, profound scholarship, perspicuity and eloquence of expression, painstaking accuracy and big ideas. My aim is to be clear and evocative, for in this way I feel more in touch with my subject that is very interesting.

This paper, therefore, presents a personal biography of A. N. Tikhonov, or rather, a poignant tribute to him. It is the fruit of my attempt to understand and ingest Tikhonov's works over the course of several years. This paper follows him from when he was a child to his death. An honest appraisal of Tikhonov's life and work will be my main goal.

Andrei Nikolaïevitch Tikhonov was one of the most eminent contemporary mathematicians from all points of view. He was an innovator, pioneer, icon, and a bright famous Soviet and Russian mathematician and geophysicist. He had a fascinating appearance and spoke with a cheerful and positive attitude. Tikhonov was always dressed with respect and detail to his finer characteristics. At the same time, he had a native wit, wisdom, humanity, self irony, and a great sense of humour. He was a man with a big smile.

He was born on Tuesday, October 30, 1906, in the town of Gagarin (previously Gzhatsk), in Smolensk region (West Russia) and died on Monday, November 8, 1993 in Moscow and has been buried in Novodevich'e Cemetery. He is gone but not forgotten.



Figure 2: A. N. Tikhonov [23]. (1906-1993) Permission to use this photo was obtained from Pavel Yaskov.

2. Early life and education

Andrei Nikolaïevitch Tikhonov was born into a wealthy family of high social standing and prestige. He was the second of two children of Nikolai Vasilievich Tikhonov (his father), who was a merchant, and Mariya Nikolaevna (his mother), who was warm hearted, capable and energetic. She took care of their two sons (Andrei (the youngest) and Nikolai (the elder)) [20], who grew up together and were given the best education. In 1910 the Tikhonovs moved to Moscow, where the boys visited a city's gymnasium (secondary school).

When A. N. Tikhonov was 15, he went on to study at the Mathematics Department of the Moscow State University (MSU) Faculty of Physics and Mathematics.

After completing secondary school in 1922, Tikhonov entered the faculty of physics and mathematics at Moscow State University and made remarkable progress, having his first paper (related to results of Pavel Sergeevich Aleksandrov and Pavel Samouilovitch Urysohn on conditions necessary for a topological space to be metrisable) published in 1925 while he was still 19, and in the middle of his undergraduate course. In other words, as P. S. Aleksandrov summarized [1]: "Tikhonov began his scientific career in a brilliant way at the age of 19 by obtaining several remarkable topological results, which soon made him world famous".



Figure 3: A. N. Tikhonov's family in 1910 [12, 25]: From left to right: (1) Mariya Nikolaevna (his mother), (2) Nikolai (his brother), (3) Andrei N. Tikhonov (4 years) and (4) his father Nikolai Vasilievich. Permission to use this photo was obtained from Zaikina Galina.

Tikhonov earned his Ph.D. in 1927 under the direction of his supervisor P. S. Aleksandrov, who was only ten years his senior. His work focused on general topology as well as functional analysis of equations of Volterra type and their applications to mathematical physics [22]. In 1936 he defended his habilitation thesis for work on Volterra functional equations. Tikhonov was appointed as a professor of Moscow State University after successfully defending his thesis [22].

3. Some Positions Held by Tikhonov

As the British statesman Winston Churchill said [7, page 2]: “The price of greatness is responsibility”. Tikhonov held many academic and research positions; for instance:

- He taught mathematical physics.
- He was appointed head of the Department of Mathematics of the Moscow State University (MSU) Faculty of Physics (in 1937) [12].
- He took up the Chair of Mathematics at Moscow University [8].



Figure 4: On the left, A. N. Tikhonov at age of 18. [12, 25]. On the right, A. N. Tikhonov at age of 40. [25]

- He was a former Department chief (in 1960) at the mathematics, mechanics, and physics faculties.¹
- He served as director of the M. V. Keldysh Institute of Applied Mathematics (1978-1989) [12].
- He was the founder and the Dean of the Faculty of Computational Mathematics and Cybernetics of the Moscow Lomonosov State University from 1970 through 1990 [12].
- He was deputy director of the Institute of Applied Mathematics of the USSR Academy of Sciences [8].

4. Research Work

Tikhonov was keenly interested in many areas of mathematics and geophysics. His circle of interests was not restricted to one area only, it was very wide. He made major advances in many fields; his work and expertise covered a broad range of topics. He contributed substantially to:

¹*Andrej Nikolaevich Tikhonov (1906-1993)*, by A. A. Tikhonova and N. A. Tikhonov, Physics Department of the Moscow University, 2004, 124 pages. Text in Russian, available at <http://www.phys.msu.ru/upload/iblock/4bb/tikhonov.pdf>, last accessed on January 28, 2018.

Topology: Topology was his first area of interest. Tikhonov's reflections led him to several fundamental topological discoveries [2]. He is best known for his work in topology: Metrization Theorem proved in 1926, and Theorem of Tikhonov in 1930, which states that every product of many arbitrarily compact topological spaces is again compact in the sense of the product topology [17, 22]. This famous theorem holds first place for the number of citations [2]. Tikhonov defined the completely regular spaces called Tikhonov spaces in his honor [2].

Functional Analysis: Tikhonov went from topology to functional analysis with his famous fixed-point theorem for continuous maps from convex compact subsets of locally convex topological spaces [22].

Mathematical Physics: The results he obtained are of importance in both topology and functional analysis. They were applied by Tikhonov to solve problems in mathematical physics [22].

His research on mathematical physics may be classified as follows [21]:

1. Theory of thermal conductivity and equations of parabolic type.
2. Electrodynamics: Including calculations of electromagnetic oscillations propagation in wave-guides, in layered medium, in conductive mediums/bodies [20].
3. Theory of differential equations with small parameters.
4. Research in computational mathematics.
5. Fundamental uniqueness theorems proved for the heat equation and study of Volterra integral equations.
6. Research on inverse problems and incorrectly formulated problems: Tikhonov regularization, considered the most known stabilising technique and one of the most widely used methods to solve ill-posed inverse problems, is named in his honor. This method is always employed in order to reduce the influence of the measurement errors on the numerical results [11].
7. Certain classes of well-posed problems.

Geophysics: Tikhonov worked on geothermal topics but his geophysical studies were far from being restricted to those. He made a major contribution to the use of electromagnetic fields for studying the structure of the Earth's crust, especially the use of the natural electromagnetic

field for obtaining a complete electrical section of the crest. His method consists of comparing the electric and magnetic components of the natural field at the surface, which gives the properties of the layers, if a broad frequency spectrum is used, it is possible to evaluate the electrical structure down to depths of hundreds of km [21]. He was also one of the inventors of the magnetotellurics method in Geophysics.

Other applied problems: Numerous solution algorithms of various applied problems [16], especially of optimisation problems [20]. Tikhonov was skilled in Numerical Analysis [18].

All in all, Tikhonov conducted research in many areas of mathematical physics and mathematical modeling.

5. Tikhonov's Students and Colleagues

Tikhonov had a great sense of responsibility in his work and a great warm-heartedness towards all his colleagues and students. It was a privilege to work alongside him. He was internationally known as a role model and wonderful mentor. He helped hundreds of students, by preparing their letters and allowing them to be involved in research early on [18].

Tikhonov used to say [12]: “If you have substantial arguments, just come out to the blackboard with chalk in your hand and show them”.

His seriousness, good will, and at the same time, stringent requirements on science and the work of his staff created a very special atmosphere at the institute, and called for the highest standards of scientific activity [12].

Some of his talented students and outstanding colleagues are cited below:

- Anna Khalilovna Pergament: 37 scientific articles. (Tikhonov was Pergament's dissertation advisor (1965).)
- N. Alexander Marchenko: 21 works in 46 publications (in 2 languages) and 275 library holdings.
- Adelaida Borisovna Vasil'eva (born in 1926): over 130 papers. (She was a gifted pupil of Tikhonov. Vasil'eva began to undertake scientific research under Tikhonov's supervision.)

- Vladlen Borisovich Glasko (1928-2003): Professor, Doctor of physico-mathematical sciences. (Glasko was a co-author and colleague.)
- Vladimir Aleksandrovich Il'in (1928-2014): Member of the Russian Academy of Sciences, Professor, Doctor of physico-mathematical sciences (1958), documents indexed: 357 Publications since 1950, including 15 Books. (Tikhonov was Il'in's dissertation advisor (1953) and (1960).)
- Alex V. Lukyanov: Senior Research Fellow/Lecturer in Applied Mathematics. Ph.D. (1994) from I.E.Tamm Theoretical Physics Department. (Lukyanov was Tikhonov's colleague.)
- Boris Leonidovich Rozhdestvenskii: Total publications: 28 (among them 24 Scientific articles).
- Aleksei Georgievich Sveshnikov (born in 1924): Ph.D. from Lomonosov Moscow State University (1953). (Tikhonov was Sveshnikov's dissertation advisor (1953).)
- Valentin Fedorovich Butuzov (born in Russia on November 23, 1939): He is a Doctor of physicomethical sciences (1979) and belongs to the staff of the Faculty of Physics of M. V. Lomonosov Moscow State University, 38 works in 87 publications (in 4 languages) and 444 library holdings. (Adelaida Borisovna Vasil'eva was Butuzov's dissertation advisor (1966).)
- Alexander Andrejewitsch Samarskii (1919-2008): In 1948 he defended his Ph.D. Thesis. Awarded the Stalin Prize (1954), he became a Doctor of Science (1957), awarded the State Prize for his work on the theory of difference schemes (in 1999). (Tikhonov was Samarskii's dissertation advisor (1948).)
- Dmitrii Pavlovich Kostomarov (Birth date: March 22, 1929): Lomonosov Moscow State University, Member of the Russian Academy of Sciences, Professor, Doctor of physico-mathematical sciences. (Tikhonov was Kostomarov's dissertation advisor.)

Other names: V. Ya. Arsenin, V. B. Mitrofanov, D. N. Chetaev (all three were Tikhonov's co-authors and colleagues), and V. M. Volosov (Tikhonov was Volosov's dissertation advisor (1956)).

6. Tikhonov's Work Related to the Soviet Atomic Project

Tikhonov and his team contributed significantly to establishing rigor and developing important tools used in modern mathematical physics. In this section we focus on how they contributed to the Soviet atomic project [12, 14].

It was disclosed that more than 500 000 people, among them 8000 scientists, were involved in the first Soviet nuclear device test. Tikhonov was one of them [12]. The main task of Tikhonov's team was making calculations on different aspects of the atomic bomb in a very short period of time (about a year).

First off, they calculated the average model of the atomic explosion. Then Tikhonov proposed a construction of the model and the calculation of the power of the atomic bomb, using complete models. I. M. Khalatnikov and others did the computation of the hydrogen bomb in parallel with Tikhonov's team at the Applied Mathematics Department headed by M. V. Keldysh [13].

The problem of solving partial differential equations at the time was considered of utmost complexity. They had no experience with such calculations, and the theory of difference schemes was virtually nonexistent. Therefore, the direct calculation of the nuclear explosion was considered by the experts as unrealistic. L. D. Landau called this settlement, if it was carried out, a scientific feat. Tikhonov suggested applying the method of finite differences to the complete system of partial differential equations. A. A. Samarskii figured out how to make parallelization between the solver-girls, distributing approximately ten equations for each.

As a result, the time for solution of several hundreds of equations has been reduced by fifteen times and was performed during two months. The calculations were carried out at the time by Felix adding machines and electromechanical calculators Mercedes. By the time of the first test of the bomb, there were already the first results of the calculations and the differences amounted to only 30%, and the error was further reduced to 10% [4].

7. His Research Output and Most Well-Known Works

Tikhonov was a a prolific author who has 174 different works in 7 languages (at least) and 4.372 library holdings. He has also given numerous talks, presentations, conferences and lectures. He was an active participant in various

symposiums on different topics of mathematics and physics, and he chaired several seminars. He organized scientific meetings and performed groundbreaking research into questions about several subjects of mathematics and physics. He was an extensive collaborator (for many decades) with well known mathematicians and physicists.

A. N. Tikhonov had a prodigious lifetime output of more than 200 original research papers. In addition, he was Editor-in-Chief of the First International Conference, held in Moscow (on ill-posed problems in the natural sciences) between August 19 and August 25, 1991 [24].

Tikhonov has authored (and co-authored) over 575 publications (treatises, textbooks, articles, monographs, ...), see Appendices A and B for comprehensive lists.

8. Honors and State Awards

Given his achievements, it is not surprising that A. N. Tikhonov received accolades from his profession. During the Soviet Union era, the career of a mathematician was one of a few relatively free of ideological pressure [18]. Because of his pioneering work and academic talent demonstrated for more than 65 years, his scientific achievements and organizational activities have been recognized, throughout his career, through a large amount of high state prizes, decorations, and awards. Noteworthy examples are listed in Appendix C.

9. Epilogue

As the Scottish philosopher Thomas Carlyle said [10, page 141]: “No great man lives in vain. The history of the world is but the biography of great men.” The American poet Henry Wadsworth Longfellow noted that “When a great man dies, for years the light he leaves behind him, lies on the paths of men.” “It is natural to die as to be born” [3, page 256], as the British statesman and philosopher Francis Bacon said.

Professor A. N. Tikhonov passed away at a ripe old age of 87 [22], leaving behind a huge legacy. He was a visionary, and there is no way to fill the gap his loss causes, especially for many scientists (that he was a close friend to), who can recognize the magnitude of such a loss. His death was a great, and

deep sorrow. His name will be forever inscribed in the history of both Soviet and Russian mathematics and well beyond.

Tikhonov was a vivid example of a talented personality devoted to mathematics, physics, and science, and in the development of research and his country [12]. His meticulous and impressive research never ceased. In fact, it seemed that he was always getting younger, stronger, a more admirable and adorable gentleman. He was truly a great scientist. I believe that this is the most fitting description. He will live on in our hearts and minds, and he will be sorely missed.

As the British writer Terry Pratchett said [19]: “Do you not know that a man is not dead while his name is still spoken?”. So, speak A. N. Tikhonov’s name.

As the French fashion designer Gabrielle Chanel said [15, page 46]: “In order to be irreplaceable one must always be different”. A. N. Tikhonov was different, so he is irreplaceable.

As the American essayist, lecturer, and poet Ralph Waldo Emerson wrote [5]: “Every great man is unique”. A. N. Tikhonov was unique.

I sincerely believe that the life story of the genius A. N. Tikhonov will inspire many ambitious students and scientists around the world to follow his path to success, to benefit from his amazing and creative contributions, to break new ground, and to make a difference in the world.

Acknowledgement

This work was realized in EDPNL Laboratory and Mathematics Department of École Normale Supérieure de Kouba, Algiers, Algeria. I would like to express my gratitude to the editors for their constructive comments and helpful suggestions. I also thank the referees for their carefully reading of this paper and for their valuable comments.

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Text in Russian, available at <http://www.phys.msu.ru/upload/iblock/4bb/tikhonov.pdf>, last accessed on January 28, 2018.

- [26] Wikipedia contributors, image: Memorial board of A.N. Tikhonov on the building of the Department of Computational Mathematics and Cybernetics, Moscow State University. Source: https://commons.wikimedia.org/wiki/File:Tikhonov_board.jpg, last accessed on January 29, 2018.

A. Some of A. N. Tikhonov's textbooks

1. Title: Equations of Mathematical Physics
Languages: English, Russian.
Authors: A. N. Tikhonov and A. A. Samarskii.
First edition: in 1951. It endured many editions. The seventh edition was published in Russia in 2004 in the series Classic University Manuals with some additional material reflecting the results obtained in recent years by A. N. Tikhonov's students and the students that descended from them [12]. This textbook became an important event in the world of mathematics. It was republished several times and translated into 13 languages, becoming one of the most widely read publications in its field.
2. Title: Nonlinear ill-posed problems
Language: English.
Authors: A. N. Tikhonov, A. S. Leonov and A. G. Yagola.
Publisher: Springer Netherlands.
Softcover reprint of the original first edition from 1998.
Edition 2014: 386 pages.
3. Title: Solutions of ill-posed problems
Authors: A. N. Tikhonov and V. I. Arsenin.
Language: English.
Publisher: V. H. Winston & Sons, Washington, D. C.
Edition (January 1977): 272 pages.
This textbook was distributed solely by Halsted Press, a division of John Wiley & Sons, Inc.
It was the first book in English on the general subject of ill-posed problems. It contains a number of annoying misprints and the translation is not the best, but it is still an important primary source [9].

4. Title: Numerical Methods for the Solution of Ill-Posed Problems
 Authors: A. N. Tikhonov, A. Goncharsky, V.V. Stepanov and A. G. Yagola.
 Language: English.
 Originally published in Russian, 1977 (258 pages).
 Publisher: Springer Netherlands, 1995 (254 pages).
5. Title: The theory of functions of a complex variable
 Authors: A. G. Sveshnikov and A. N. Tikhonov.
 Language: English, Russian.
 Publisher: Moscow Mir, 1971 (311 pages).
6. Title: Differential equations
 Authors: A. N. Tikhonov, A. B. Vasil'eva and A. G. Sveshnikov.
 Language: English.
 Publisher: Springer, 1985.
7. Title: A collection of problems in mathematical physics
 Authors: B. M. Budak, A. A. Samarskii and A. N. Tikhonov.
 Languages: English, Russian.
 Publisher: 1964 (768 pages). Reprint of 1956 edition.
 The present book is based on the practical work with equations of mathematical physics done in the Physics Faculty and the external section of Moscow State University. Much attention has been given to problems on the derivation of equations and boundary conditions. A considerable number of problems are given with detailed instructions and solutions. Other problems of similar character are given only with the answers [6].
8. Title: Méthodes de résolution de problème mal posés
 Authors: A. N. Tikhonov, V. A. Arsenin and V. Koltiar.
 Publisher: Moscow: Ed. Mir, [Paris] (23, rue Royale, 75008): [diffusion Agence littéraire et artistique pour les échanges culturels], cop. 1976, 13 editions published between 1974 and 1976 in 4 languages and held by 99 WorldCat member libraries worldwide.

B. Selected Papers

Tikhonov's prodigious lifetime output of more than 200 original research papers is hard to list completely here. We aim to present a select few:

B.1. Own Papers

1. A. N. Tychonoff (1935), Théorèmes d'unicité pour l'équation de la chaleur, *Mathematical Sbornik* 42(2): 199-216.
2. A. N. Tychonoff (1936), Sur les points invariants des espaces bicomacts, *Rec. Math. Mat. Sbornik N.S.*, 1(43):5, 775.
3. A. N. Tychonoff (1943), On the stability of inverse problems. *Dokl. Akad. Nauk. USSR* 39(5): 195-198.
4. A. Tikhonov (1948), On the dependence of the solutions of differential equations on a small parameter, *Mat. Sb. (N.S.)*, 22(64):2, 193-204.
5. A. N. Tikhonov (1950), On determination of electric characteristics of deep layers of the earth's crust, *Dokl. Akad. Nauk. USSR*, 2(73), 295-297.
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9. A. N. Tikhonov (1981), Approximate systems of linear algebraic equations, *Zh. Vychisl. Mat. Mat. Fiz.*, 20:6, 1373-1383.
10. A. N. Tikhonov (1981), Approximate functional equations of the first kind, *Trudy Matematicheskogo Instituta imeni VA Steklova*, 158, 197-202.

B.2. Co-authored Papers

1. W. Stepanoff, A. Tychonoff (1934), Über die Räume der fastperiodischen Funktionen, *Mat. Sb.*, 41:1, 166-178.
2. I. G. Petrovskii and A. N. Tikhonov (1940), *R. Courant und D. Hilbert, Methoden der mathematischen Physik*, Bd. II (review), *Uspekhi Mat. Nauk*, no. 7, 329-331.
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C. Tikhonov's decorations and awards

1. Red Banner of Labor Order: Tikhonov was decorated with three orders Red Banner of Labor (1945, 1949, 1961).
2. Lenin Order: Tikhonov was six times decorated with the Lenin Order (1951, 1953, 1963, 1966, 1971, 1986). The sixth one was given to his 80 years birthday, in 1986, for exceptional merit in the development of mathematical science and training of scientific workers [12].
3. Stalin Premium (1953) (for his successful work in atom project).
4. Lomonosov Premium (1963) (for his research: On solution of ill-posed problems).
5. Lenin Prize (1966) (for outstanding contribution to computational mathematics and elaboration of the theory and methods of solution of ill-posed problems).
6. Tikhonov became a corresponding member of the USSR Academy of Sciences on 29 January 1939. He was also elected to full membership of the USSR Academy of Sciences on 1st July 1966.
7. October Revolution Order (1975) (to the 250 anniversary of the Academy of Sciences).
8. Premium of the USSR Council of Ministers (1981).
9. Medal of Hero of Socialist Labor (1954, 1986).
10. Keldysh Gold Medal (1990), for series of works: On Regularisation Methods in Broad Spectrum of ill-posed Problems of Mathematical Physics.