From the History of Physics

YURIĬ ALEKSANDROVICH KRUTKOV

V. Ya. FRENKEL'

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THE year 1970 marks the eightieth anniversary of the birth of Yuriĭ Aleksandrovich Krutkov (1890–1952) who was a corresponding member of the USSR Academy of Sciences and a professor at the Leningrad State University.

Krutkov was a member of the first generation of Soviet physicists; moreover, he was perhaps the first "pure" theoretical physicist in Russia. His research was at first connected with statistical theory and with Planck's and Einstein's quantum theory. He followed the same course which this area of science followed from the classical work of Boltzmann and Gibbs to the emergence of the Bose-Einstein and Fermi-Dirac statistics, but then he concentrated around problems of mechanics, especially statistical mechanics.

Krutkov played a prominent role in the organization of physics in the Soviet Union and in Leningrad particularly, in the establishment of contacts of Soviet physics with physics in the West, and in the achievement of that high prestige which it was already beginning to enjoy there in the Twenties. Krutkov was a fine lecturer who indeed can be regarded as one of these who have taught several generations of students in the departments of Physics and Mathematical Mechanics at Leningrad State University. This all defines and justifies the interest in his personality and works—the more so, because unfortunately nothing has yet been specially written about him. (We note, that it is very nice to see his photograph among the comparatively small number of pictures of prominent Soviet physicists which adorn the pages of the two-volume Razvitie fiziki v SSSR (Development of Physics in the USSR), issued on the Fiftieth Anniversary of the Soviet Government.

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I. Yuriĭ (Georgiĭ) Aleksandrovich Krutkov was born May 29, 1890, to an educated family in Petersburg. His father, Aleksandr Fedorovich Krutkov, was graduated from the Petersburg University in the Department of History and Philology in 1871 and had devoted himself to a career as a teacher. He taught Russian, Latin, and Greek. Apparently he possessed outstanding aptitudes for the humanities which doubtlessly his son inherited.

During his university years, A. Krutkov had become closely acquainted with Tsvetaev, who was famous in Russia at the close of the last century as a cultural figure, director of the Rumyantsev Museum, and organizer of the "Museum of Traces and Relics of the Culture of Various Eras," later renamed the Museum of Fine Arts. The friendship of Tsvetaev and the senior Krutkov was not broken even after the departure of the Krutkov family from Petersburg. Proof of this has been preserved in an archive left after the death of the younger Krutkov.

After working for some time in the secondary schools of Petersburg, Krutkov senior went to the Ukraine, where he became a director of a secondary school, first in Zlatopol' and after 1891 in Lubny, a small town on the Poltava Province, which possesses a very ancient history and is mentioned in the manuscripts of the 12th century. Here, not far from Mirgorod and other places made memorable for us by Gogol', the physicist Yu. Krutkov spent his childhood. In 1906 Aleksandr Krutkov, wishing to prepare his son for the university, took him to Petersburg and soon after, his entire family moved there too. In 1908 young Krutkov graduated from the Twelfth Petersburg Gymnasium (secondary school) with a god medal and entered the university in the Department of Mathematics and Physics.

In the Leningrad section of the Archives of the USSR Academy of Science, there are papers of the young Krutkov which relate to his stay at the university.[1*] Familiarization with these materials, including lecture notes, summaries of articles, and rough drafts, permits one, even without turning to friends of this physicist, to form a sufficiently full and, let us hasten to add, surprisingly favorable impression of him.

One's attention is drawn first to the distinctive decoration of Krutkov's notebooks. Each of them was adorned with excerpts from the works of the classic literary writers, of ancient philosophers, of physicists, and of mathematicians whom he admired. Especially often this budding physicist turned to Goethe. These references, of course, bear witness primarily to the intellect and the perception of their authors. However, their selection reflects the wordly outlook and the tastes of the young Krutkov. As we become acquainted with them now, we compare them, so-to-say, a posteriori with Krutkov's own "physical mark" and find a direct correspondence between them and the particular features of his approach to physics. But probably the distinguishing feature of his thinking could also have been predicted on this basis a priori. In support of what has been said, let us cite two or three of these references. Thus with the notation "supposedly Gauss," Krutkov wrote, "All the formulae and results are ready, what alone is left to do is to find a way by which I can arrive at them."[*] And Krutkov himself in the first ten years of his career tried—as, incidentally, many others did—to prove Planck's formula for the energy distribution of radia-

*An asterisk with a number marks a published reference not by Krutkov. All other references pertain to the chronological list of his works at the end of this article.

†All references were cited by Krutkov in the language of their authors.

tion density analyzed the initial premises of the quantum hypothesis, and paved the way from them to the final result.

Krutkov performed many calculations. During World War I and in the first years of the Civil War, when obviously there was a paper shortage, he would scribble his calculations on odd pieces of paper and envelopes, back sides of bills, old notes and even letters. Here is a note from Thompson (Lord Kelvin): "Expenses for chalk are often offset by economy of the brain," or two references with a thought in common: from Dostoevskiĭ in the first chapter of Crime Punishment, "It is curious what people are most afraid of. They are most afraid of taking a new step and of uttering a new and original word!"; and comparatively close in time is his entry from Duhem: "Respect for traditions is the indispensable condition of scientific progress."

The described headpieces and humorous minatures, as well as the exact and sonorous Latin, tell us much about the fine upbringing this physicist received in his father's house and obviously under his direct influence. Several poetic works of the young Krutkov himself, written in Russian and in German, can also be found here.

One experiences a peculiar feeling when one looks over Krutkov's summaries. Here one finds Maxwell's Electrodynamics ("A Treatise in Electricity and Magnetism"), a Kirchhoff's "Mechanics," and articles by N. E. Zhukovskiĭ. And then there are detailed summaries of articles by Einstein, Planck and Debye, with reconstruction of the intermediate calculations that had been omitted. When someone is very attentive to the great men of his field and draws his knowledge from the primary source, this always calls forth respect: however, in this case, suddenly you remember that Krutkov was the contemporary of these great men and that he took their articles not out of old journals preserved in the depositories of the libraries, but out of fresh issues which had just appeared on the shelves.

The entries of the lectures of O. D. Khvol'son and I. I. Borgman, his journals of laboratory work in physics carried out at the university and accepted by Karl Karlovich Baumgart (how many generations of physicists passed through his hands!), and the aforementioned summaries of books and articles—all these give an impression of Krutkov's surprising accuracy and conscientiousness.

We had occasion to write about the situation which developed in the Department of Mathematics and Physics at the St. Petersburg University[2*,3*] and will not speak here about the difficulties which encountered by those young people who studied within its walls during the first seventeen years of this century and who had decided to devote themselves to teaching and to research within its walls. (Physics in prerevolutionary Russia was concentrated in institutions of higher learning.) In the years indicated, B. P. Bursian, G. G. Veĭkhardt, Yu. A. Krutkov, and V. M. Chulanovskiĭ constituted a cell of these young people. The student friendship among them was preserved and strengthened even later when V. K. Frederiks, P. I. Lukirskiĭ and V. I. Pavlov joined their company. In Krutkov's letters, he refers to "Burs" (Bursian) and

Yu. A. Krutkov the year he entered the university (Courtesy of The State Historical Archive of the Leningrad Oblast').

"Freddi" and there are glimpses of the affectionate nickname for V. M. Chulanovskiĭ. (As for Krutkov himself, his friends affectionately called him "Krut.")

Krutkov's first student years and the beginning of his scientific career were inseparably linked to Paul Ehrenfest and his Petersburg physics seminar which met from 1908 to 1912 before the departure of Ehrenfest for the Netherlands. Krutkov was the first (chronologically) in a long line of brilliant students of Ehrenfest's. He was among the organizers of and active participants in a student circle at the university, and from his notes we learn that in the year 1911 alone he gave a whole series of papers there on his experimental and theoretical research of Brownian motion, on the Drude theory of electron gas, and on the special theory of relativity.

In the fall of 1913 Krutkov went to visit Ehrenfest in Leiden for several months, travelled about the country, and took part not only in the projects of the Ehrenfest seminar in Leiden, but also in a colloquium of Lorentz's in Haarlem and in meetings of physics seminars in other cities in The Netherlands—Utrecht, Dordrecht, and Amsterdam. He returned to Petersburg in the winter of 1914 and soon received a postcard (which is preserved in his archive) from Dordrecht dated March 26, 1914: "Dear Mr. Krutkov: Heartfelt greetings from the participants in an exceptionally productive colloquium. A letter will follow soon." It was signed by Ehrenfest, Veĭkhardt, Einstein, Droste, Kern and Keesom.

II. The first work by Krutkov was directly connected with the research of his teacher, Ehrenfest, and was concerned with the most vital problems of quantum theory at that time. This is a theory which in the words of Krutkov was continuing to "remain a branch forcibly grafted upon the tree of statistical mechanics."[4]

It is well known that in his work on the theory of quanta, Einstein started not from the Planck formula for the density of radiation, but from the formula which Wien had proposed even before the work of Planck and which agreed with the data of experiments

at high frequencies. Einstein specially stipulated that all the results of his work were correct in the same degree and within the same limits as was the Wien formula. The result of a series of studies by Einstein was his formulation of the hypothesis of light quanta, which, according to Ehrenfest, leads to the following three assertions:

1. A Planck resonator with frequency ν can possess only the following set of energy values: 0, $h\nu$, $2h\nu$, ...

2. These energy values turn out to be a composition of some number of elementary, mutually independent batches of energy $h\nu$.

3. Light quanta behave like atoms not only in processes of emission and absorption of light by Planck resonators, but also in space free from the "usual" matter, i.e., in vacuum.

Let us note that Planck[5*] regarded only the third of these assertions as completely alien to his theory of radiation.

In his first published article (1914[1]) Krutkov with the aid of a variant of Ehrenfest's and Afanas'eva-Ehrenfest's statistical "urn model" (see also[3*]) showed that already the second of these assertions (i.e., the hypothesis of independent atoms of light) as it was formulated by Einstein, leads to Wien's formula rather than to the Planck's formula, the correctness of which at that time had been completely supported experimentally. In this way, in contrast to what had been supposed (particularly by Planck himself), even the second of the stated assertions needed some modification and the way to such a modification had been mapped out back in the early work by A. F. Ioffe on the existence of "associations" of light quanta which Ioffe called "molecules of light."

We shall not abstract in greater detail this and other work of Krutkov relating to the period cited. This work completed from 1914 to 1923, i.e., during the years of transition from the quantum theory of Planck, Einstein and Bohr to quantum mechanics, gave rise to a series of lively polemics,[8*,3,9*] but is now of only historical interest. However, it should be added that this work also was rich with methodological finds by the young author. Particularly noteworthy of these was the outstanding survey "On the Theory of Quanta"[4] which contains a wealth of memorable images and analogies. Everyone ought to acquaint himself with this survey if he wants to capture the atmosphere of those years of the "quantum crossroads" and—if we may use the words of Lorentz—"the necessarily temporary character of the theory."[10*] But even those who would read his lectures on mechanics and statistical physics without shunning historical details, could find a lot of useful material in the cited works of Krutkov.

These assessments can also be related in no small degree, from our viewpoint, to another survey by Krutkov which is also based on his own work, namely the lengthy article "Adiabatic Invariants," dealing with conditionally-periodic systems and adiabatic invariants.[7,8] This was published simultaneously in "Trudy" (Transactions) of the Optics Institute and in the Journal of the Russian Society of Physics and Chemistry (ZhRFKhO)[9]. Even here Krutkov's style is reflected in the excellent knowledge of the history

Participants in Ehrenfest's seminar in Petersburgh in 1910. Seated—P. S. Ehrenfest, V. M. Chulanovskiĭ, G. Perlitz, T. A. Afanas'eva-Ehrenfest; standing (from left to right)—L. D. Isakov, A. F. Ioffe, Yu. A. Krutkov, D. S. Rozhdestvenskiĭ, G. G. Veĭkhardt, A. I. Tudorovskiĭ, V. R. Bursian, K. K. Baumgart, and Ya. R. Shmidt.

of the problem and the masterful exposition of the subject. He wrote a concise and clear mechanistic introduction to the entire paper as a whole, and then, starting with a series of concrete examples such as the theory of gases and the theory of radiation, the problem of the pendulum with a mobile suspension (the Rayleigh-Einstein variable-length pendulum) and examples from celestial mechanics, he gave a lively presentation of adiabatic invariants, after which he passed to their general theory and to a survey of work on the ergodic and the quasi-ergodic (Ehrenfest) hypotheses. Krutkov's work represents the fullest and most general theory of adiabatic invariants, the significance of which, as Ehrenfest has shown, is exceptionally great, because these are the only quantities that can be quantized. Whereas before Krutkov's work all that was verified was the existence of adiabatic invariance of some quantities, it was Krutkov who developed a general method for finding the adiabatic invariants of the corresponding systems. However, the role of this work by Krutkov also turned out to be limited by the sheer force of the aforementioned "intermediate" character of quantum theory, which was the threshold of quantum mechanics. Thus all these investigations by Krutkov shared the fate of the work of his teacher Ehrenfest: in the new edifice of quantum mechanics, they existed in the form of original "hidden parameters," or rather, they were the scaffolding from which the facade of this theory was freed when its construction had been completed.

III. Yuriĭ A. Krutkov did a great deal for the organization of Soviet physics in the first years after the revolution. Without any exaggeration whatever, we can assert that he played a direct role in all efforts concerning the establishment of physics research studies in Petrograd. Research in physics here in 1918 and 1919 could be called with good reason "microphysics"—so small was the number of its representatives and so few were the scientific centers. But then, with the support of the Soviet Government, these began to spring up: the X-ray and Radium Institute appeared—Krutkov became an active member of it and, together with Bursian, represented theoretical physics there;

the Atomic Commission was created—Krutkov was a member of it; and D. S. Rozhdestvenskiĭ headed the Optics Institute--Krutkov, although not working directly at the Institute, attended its meetings and seminars and published his works in the "Trudy" (Transactions) of the Institute. In 1919, A. F. Ioffe organized a Department of Physics and Mechanics at the Polytechnic Institute; Krutkov was immediately invited to give a lecture there and he accepted this invitation.* D. S. Rozhdestvenskiĭ, V. A. Steklov, V. I. Smirnov and other professors at Petrograd University concerned themselves with a reform of teaching in the Department of Physics and Mathematics; Krutkov took part in this work also and became a professor at the university in 1921. In 1922 he was elected Chairman of the Physics Section of the Russian Society of Physics and Chemistry.

In his later career Krutkov became more and more closely connected with the university and with the Mathematics and Physics Institute of the Academy of Science in the years when A. M. Krylov and S. I. Vavilov were directors of this institute. In the Thirties he headed a department of the Institute of Military Mechanics.

We shall examine now some of the details of Krutkov's activity with the aforementioned Atomic Commission and his participation in the work of this commission.

On December 24, 1919 the newspaper Krasnaya Gazeta informed its readers that "a commission consisting of three astronomers, three mathematicians, three theoretical physicists and ten scientific calculators will commence work in a day or two at the Petrograd Optics Institute. Professor Rozhdestvenskiĭ will be in charge of all the work of the commission. Because the work of the commission, added the newspaper, "is rather strenuous, the question has been raised of issuing special rations to all these scientists."

Sessions of the commission were held regularly in the twenties in cold and hungry Petrograd. Minutes were carefully kept and have been preserved in the D. S. Rozhdestvenskiĭ collection in the archives of the USSR Academy of Science.[11*] These minutes show that all the members of this commission participated regularly in its work--D. S. Rozhdestvenskiĭ, A. F. Ioffe, A. I. Tudorovskiĭ, (i.e. three physicists); A. N. Krylov, N. I. Muskhelishvili, A. A. Friedman and Ya. D. Tamarkin (four mathematicians); and, finally, B. P. Bursian, Yu. A. Krutkov, and V. K. Friederiks—obviously the three theoretical physicists mentioned in the newspaper. Who the newspaper had in mind when it spoke of astronomers remains unclear. At their meetings the members of the commission read papers, the texts of which were appended to the minutes. We find here papers by practically all the persons mentioned above,† and, in particular, papers by Krutkov, such as "On the Motion of the Electron under the Action of the Atom in a Magnetic Field" (read on February 19, 1920), "Periodic Systems and the Hypothesis of Quanta" (April 15, 1920), and several minor communications. Point Four of the resolution accepted at the first meeting of the Atomic Commission shows eloquently how life was treating Krutkov in those years: "Provide Yu. A. Krutkov with kerosene and firewood in order to make it possible for him to work productively at home.

Krutkov was the first Soviet scientist to receive one of the one-year stipends from the Rockefeller Foundation that were given to the most talented young physicists and that enabled them to work in various physics centers in Europe. He spent 1922–23 in Germany and the Netherlands. Those were the years of intensive mending of scientific ties between the young Soviet physicists and the powerful schools of physics that had been formed in Germany, England, The Netherlands, and France. An essential component in this work was the purchase of books and apparatus for the Optics and X-ray Institutes, for the Petrograd University, and for the Academy of Science. The distinct headquarters of the numerous groups of Soviet physicists carrying out this work were situated in Berlin. This was where Krutkov met and helped A. A. Arkhangel'skiĭ, S. A. Boguslavskiĭ, M. M. Glagolev, L. V. Myslovskiĭ, V. M. Chulanovskiĭ, and others. Here in Berlin he often met with O. D. Khvol'son who would come on business from Petrograd and Ivan Petrovich Pavlov stopped in Krutkov's room here on his triumphal trip to the U.S.A. Of the German and Dutch physists with whom Krutkov had contacts in Berlin, Göttingen, Rostock, Jena, Bonn, and Leiden, let us name first of all Einstein, Lorentz, Debye, Kammerlingh Onnes, Stern, Gilbert, F. Frank and, of course, Ehrenfest. (Of Lorentz he wrote on April 15, 1923: "On Thursday I was fascinated by a visit at Lorentz's. What a marvellous man![1*]) The chronicle of Krutkov's life in that period can be followed from letters to his sister Tat'yana, which she carefully preserved. Because of the shortage of space, we shall confine ourselves here to only two excerpts from them, not counting the one just given; "April 29, 1923, Leiden—I am fed, shod and clad. I smoke my pipe as often as I want and use up lots of paper with calculations, i.e., I am happy." "September 22, 1923, Berlin--I returned on the evening of the twentieth from a congress of physicists in Bonn where I heard many compliments concerning my previous works and my new paper. But you know such things don't move me. They don't even give me pleasure."[1*]

In the years 1925 and 1926 Krutkov was again in Germany and France. This time he associated most of all with the Göttingen physicists and mathematicians in Born's and Hilbert's seminars respectively. At that time an especially large group of Leningrad physicists had gathered in Göttingen--A. N. Arensen'eva, V. R. Bursian, S. I. Vavilov, P. L. Kapitza, V. N. Kondrat'ev, P. I. Lukirskiĭ, N. N. Semenov, and Ya. I. Frenkel'. The Soviet colony lived in Frau B. Wende's boarding-house which was well-known in those years and made famous in the physicists' humorous ditties; Krutkov lived there too. Before Göttingen he had gone to Hamburg (which is where Otto Stern, who interested Krut-

*It is curious to note that Krutkov began his pedagogical activity with students at the Polytechnic Institute still earlier, as a teacher of German.

†Among those papers are two unpublished studies by A. A. Fridman: "The Motion of an Electron under the Effect of an Attracting Atom and of an External Electron Moving in a Given Manner" and "On the Principle of Dimensionality in the Theory of Adiabatic Invariants." This study was worked out by Fridman together with Ya. D. Tamarkin.)

kov, had moved to from Rostock). Here Krutkov met Ya. I. Frenkel'. Frenkel'wrote to his parents (March 14, 1926); "My landlady yesterday put a guest, Yu. Krutkov, in the room adjacent to mine. I am exceedingly glad that he has come; I have been spending the time quite pleasantly and usefully with him. Until late last night, we engaged in reading, commentary, and in part in further development of a new article by Heisenberg on quantum mechanics. Krutkov is an extraordinarily nice and pleasant fellow; in one day of our stay together in Hamburg, I have gotten to know him better than in five years of life together in Leningrad. From the middle of April to the beginning of August I will work with him in Göttingen and probably to a considerable extent we shall be working together. We both suffer from laziness, but collectivism in this case is the best antidote."[12*]

It is appropriate to say a couple of words in connection with this passage about the "laziness" of Krutkov mentioned here. His friends often and with a benevolent smile used to remember it and still do, while adding that if Krutkov had not suffered from such "laziness" he might have done a lot more for physics. But where can you place the limits on what a man could have done? An examination of the Krutkov scientific legacy, his workbooks and his papers which were referred to above, refutes the notion that Krutkov was abnormally inclined to a peaceful siesta, a notion which Krutkov himself with his peaceful, unhurried manner, his love of reading and enjoyment of sailing did not prevent from spreading. It would be wonderful if all physicists were lazy to the same degree as Krutkov and Frenkel' were.

IV. The name of Krutkov is presently perhaps most often remembered in conjunction with the role he played in the celebrated debate arranged between Einstein and A. A. Fridman. Interest in this debate marked the stormy development of astrophysics and relativistic cosmology. The substance of the debate is so well known (It was reflected in part on the pages of Usp. Fiz. Nauk in the issue in honor of the 75th birthday of A. A. Fridman[13*]) that it is not worth repeating here. Even Einstein himself in his second note and response[14*] to Fridman's[15*] work mentioned Krutkov's participation in the explanation to Einstein of the erroneous nature of his criticism of Fridman's work on an nonstationary universe. It is interesting to bring in here excerpts from Krutkov's letters and notebooks, which fill out the picture.[1*] The exact dates figuring in these excerpts put this important episode in special relief.

During his annual professional trip abroad in 1922-1923, Krutkov was often in Leiden for extended periods and continued to work with Ehrenfest there. In the spring and summer of 1923 he spent about three months in the Netherlands. In May of that year, Einstein came to Leiden and took up residence in Ehrenfest's house. Obviously with the very closest cooperation of Ehrenfest (who, by the way, had known Fridman well during his stay in Petersburg in the years 1907-1912). Krutkov managed to become acquainted with Einstein. On May 4, 1923, Krutkov at the end of a letter to his sister wrote: "I can't write anymore, however, because I have to hurry to hear a paper by Einstein. He is a very warm (gemütlich) person."* A short note in one of his workbooks reads: "On Monday, May 7, 1923, Einstein and I read the article by Fridman in Z. Physik, Bd. 10" (see[15*]) This note is preceded by formulae and computations from Fridman's article. And here is an excerpt from the letter to his sister of May 18th: "Today Lorentz gave his last lecture—he is retiring—and he quoted me. At five o'clock Einstein was discussing his most recent work with Ehrenfest, Droste and some Belgian... I won over Einstein in an argument about Fridman. The honor of Petrograd is saved!" However, judging from the date of Einstein's response mentioned earlier.[14*] Krutkov's discussions with him about Fridman's work were continued in Berlin as well; from the correspondence with Krutkov's sister, it is apparent that they met there in June. One of Krutkov's students—Academician V. A. Fock—also wrote about this: "Yu. A. Krutkov...at Fridman's request met with Einstein in Berlin and with great difficulty—as he told me—convinced him of his error. As a result of the discussions between Krutkov and Einstein, a second note by Einstein quickly appeared in which he admitted his mistake completely and gave a high rating to Fridman's results."[13*]

It is interesting to note that soon after the events just described, Fridman himself turned up in Berlin on the way to and from a congress held in Norway. On August 9th, Krutkov wrote to his sister: "Fridman has been with me although he has now gone to Hamburg for a short time. Einstein's note which rehabilitates him and which I had obtained, has already been published." On August 29th he wrote: "Fridman is returning home from Norway tomorrow." Then on September 12th: "Yesterday I spent the evening with Anna Bogdanovna (Feringer—V. F.), Shcherbatskiĭ, and Fridman. The latter two are leaving on the 15th."†* Unfortunately, it is not well known whether Fridman personally met Einstein during these trips to Berlin; similarly, it is not known whether they met when Fridman was in Berlin a year later in the spring of 1924.

V. Krutkov took practically no part in the research on the foundation and development of the new quantum mechanics, although he was a direct witness of its emergence. (Let us recall that he spent 1925 and 1926 in Göttingen, Hamburg and Berlin.) He confined himself here to the role of publicizer of the new ideas by acquainting the Leningrad physicists with the basic works of the creators of this theory. He did this in an organized set of lectures which he gave at Leningrad University or at the seminar at the University under the aegis of P. I. Lukirskiĭ and S. É. Frish, and also at the Institute of Mathematics and Physics of the USSR Academy of Science.‡

*Krutkov used to write the greater part of his letters in German.

†In the curriculum vitae that appeared in the Selected Works of Fridman published in the series "Classics of Science [16*]" (See page 389) the date of his trip to Norway was mistakenly given as summer, 1922.

‡It is fair to say the same thing, by the way, in reference to the general theory of relativity as well. Krutkov did no work on its development; in connection with this, V. A. Fock [13*] wrote that Krutkov gave lectures at the University on the general theory of relativity (along with V. K. Frederiks, A. A. Fridman, V. R. Bursian, and others.)

Of course, mechanics and, particularly, statistical mechanics, did not cease to exist upon the appearance of quantum mechanics and statistics, which a fair number of young Soviet theoreticians strove to develop. Krutkov was one of the most striking figures who continued to develop these far from exhausted areas of science, wherein new applications continue to be found even now. I think that Krutkov would have heartily agreed with the admission that one of our prominent theoretical physicists made recently, that with all the power and attractiveness of the contemporary theory of elementary particles and strong interactions, he still prefers classical mechanics with its characteristically strict and precise formulations of problems, which allow one to seek their solutions free from "phenomenological additions."

Krutkov's own active scientific interests inclined away from the Planck-Einstein theory of quanta more and more, to the side of statistical mechanics and simply mechanics. He gave courses on both of these as well as on statistical physics at Leningrad University in the Twenties and Thirties. In the first half of this period, he interested his student and co-worker at the University, V. A. Fock, in giving lectures and conducting seminars. (By the way, Fock was the first person to give a systematic course on quantum mechanics at this university.)

Here it is appropriate to say, on the basis of comments by G. A. Grinberg, V. I. Smirnov, V. A. Fock and S. E. Frish that Krutkov was a really superb lecturer not only in choice, freshness, and novelty of his material but also in the outer form of his presentation to his audience. When there was a revision in the teaching of physics, mechanics and mathematics in the Department of Mathematics and Physics at the University, it was precisely Krutkov who was given the responsibility for working out the program in mechanics and for conducting a lecture course in mechanics as a constituent part of theoretical physics. Krutkov's course in mechanics was one of the first in the USSR and probably the first at Leningrad University to be presented in the vector form, a form that was to experience not a few difficulties in taking root in our country. (See in this regard[12*], p. 132.) His lectures on statistical mechanics were also just as profound and original.[*] V. I. Smirnov remembers these lectures well. He has said that Krutkov impressed him as a brilliant improviser; he would lecture without any special preparation, it seemed. However, is not this seeming freedom from a previously thought-out lecture plan an indication of the lecturer's mastery of his subject? In the Thirties Krutkov used to give his course on statistical mechanics in the little physics auditorium at Leningrad University. Smirnov's class would meet there right before Krutkov's. Smirnov would often stay and get real satisfaction out of listening to Krutkov. During those years some notions of measure theory were beginning to penetrate the field of statistical mechanics. This theory is now one of the basic axioms of statistical mechanics. (Problems in this field dating back to Boltzmann, Poincaré, and others, can be easily formulated in the language of measure theory, see[17*].) Krutkov loved to discuss scientific articles with Smirnov and often came up with scientific propositions as soon as their conversation touched upon problems of mutual interest, and invariably these propositions would be accepted.

Frequently present at Krutkov's lectures was S. É. Frish who has added that often the contents of these lectures would be found later in print as part of Krutkov's original articles. Thus Krutkov reversed the usual procedure whereby a lecturer includes in his course the results of his own research after these have been published. Krutkov's research work seemed to grow out of the process of preparing for class.

One might think that the whole series of studies by Krutkov on the theory of Brownian motion--one of the most significant of his creative work--came about in just this way,[25,29,31,32,34-38,40-42] but in fact the theory of Brownian motion was developed before Krutkov's eyes in the first decade of this century. In the Netherlands, in Leiden, the became familiar in detail with the significant contribution to the theory that was made by H. A. Lorentz's daughter, H. de Haas-Lorentz (Einstein held her work in very high esteem.) During the Thirties, the theory of Brownian motion became the subject of study and investigation for a series of Soviet theoreticians--B. I. Davydov, M. A. Leontovich and others. In Krutkov's cycle of studies on Brownian motion his distinctive traits were apparent: in a clear and finished style he deduced the theory's basic relations between the rms momentum and the deflection of the particle with changing temperature when unordered Brownian impacts act upon the particle.[42] We will not comment on all these works but will limit ourselves to just one example which relates to the years of Krutkov's close scientific and friendly communication with Alekseĭ Nikolaevich Krylov.

VI. Krylov was the second person (after Ehrenfest) with whom Krutkov's scientific destiny was closely interwoven. They became acquainted in the first decade of this century and at first this friendship was, of course, onesided. As a young student at the University, often attending public lectures on physics and mathematics in Petersburg (Petrograd) and not missing meetings of the physics section of the Russian Society of Physics and Chemistry (of which he became a full-fledged member in February, 1961), Krutkov saw and heard Krylov in those very years when this personage was receiving recognition everywhere for his research on mathematics, on the mechanics of ships, and on the theory of marine instruments. Probably it was in 1920, as work of the Atomic Commission commenced, that the friendship of Krylov and Krutkov became mutual and closer. In addition to their common scientific interests and their fine knowledge of the history of science, both of them were highly and thoroughly erudite: not only Krylov, but also his young colleague, knew how to shine with quotations and examples from history and literature appropriately brought to bear on an issue.

*The typewritten text of Krutkov's lectures on statistical mechanics for fourth-year students at Leningrad University has been completely preserved. Publication of this course would be very desirable!

Invariably it was Krylov who was submitting Krutkov's articles to "Doklady" (Proceedings) and "Izvestiya" (News) of the USSR Academy of Science before Krutkov was elected to the rank of corresponding member of the Academy. (This occurred February 2, 1933; elected at the same time with him were P. I. Lukirskiĭ, I. V. Obreimov, D. S. Rozhdestvenskiĭ and I. E. Tamm.) Naturally Krutkov also discussed his studies on Brownian motion in detail with Krylov. The result of such discussions was a formally very simple article by Krutkov on the rolling of a ship from side to side in a rough sea.[34] In this article Krutkov used his results relating to the general theory of the Brownian motion of a vibrator[32] to solve a purely technical "marine" problem. Research on the lateral rolling motion of a ship had been done by Krylov*; his theory had connected the angle of list of the ship to the period of the wave in which the such rolling motion was occurring, and also to several other parameters. The swell of the sea and the concomittant rolling are not purely "monochromatic" processes, but occur in the form of a superposition of the waves (Krylov had called this "irregular swell"); that is, naturally, it is related to the driving force acting on the ship. But, as Krutkov noted—and this was the initial idea in his study--observation of the lateral roll with the rather crude instruments that are used in practice, permits one to "catch" the influence of only one or two purely monochromatic terms; the influence of the rest amounts to the appearance of dips in the amplitude and the phase of the rolling of the ship and these have a random, Brownian character. For this reason, Krutkov isolated (as he had done in the general theory of the Brownian motion of a vibrator) the "monochromatic" term in the force acting upon the ship. The part left after subtracting the term was presented in the form of a "Brownian component" in his general theory. In this way he succeeded in finding simple expressions of practical importance for the distribution function of the list angle of the ship and thus determine the mean values of the various characteristics of the lateral roll that are determined by this angle.

Along with numerous linear problems of Brownian motion (for example, the Brownian motion of the strings of a musical instrument, etc.) Krutkov also analyzed a particular non-linear case of rotary Brownian motion of a particle.[37,40]

The significance of Krutkov's Brownian cycle of articles found its expression outwardly in the fact that a large number of these published in 1936 as a supplement to the exceptionally interesting collection under the title "Brounovskoe dvizhenie" (Brownian motion), edited by Professor B. I. Davydov. Included in this collection were classic studies by Einstein and Smuluchowski with commentary by R. Furth.[44] The Krutkov part of this book takes up about 79 pages of text.

It should be noted here that back in the Twenties, the State Publishing House (Gosizdat) began to publish the series "Klassiki estesteovaniya" (Classics of Natural Science). P. P. Lazarev, N. K. Kol'tsov, E. V. Shpol'skiĭ and others participated in this work. This series was similar in structure and character to the famous Ostwald's "Classics of Science" published regularly since 1892 in Germany (and still being published now both in East and West Germany). Later this series was published here under the title "Klassiki nauki" (Classics of Science) with S. I. Vavilov as editor-in-chief. (Now it is headed by Academician I. G. Petrovskiĭ). Krutkov and Bursian edited and wrote the commentary for a work by Sadi Carnot in this series, "Thoughts on the Moving Force of Fire and on Machines Capable of Exploiting this Force."[16] (After a lapse of several years the translation of this memoir was reprinted.[19*])

It is impossible to ignore one more publication which was edited by Krutkov—this was H. Lorentz's "Statistical Theories in Thermodynamics" with a few appendices by Krutkov. In the editor's preface Krutkov wrote that the opportunity of publishing his appendices in this volume "with the awareness that they really do supplement it in a judicious way, we regard as a great honor for ourself."

In 1931 Krylov had Krutkov give a 30-hour lecture course to students of the Leningrad Army and Airforce Academy. He gave the lectures in the Institute of Mathematics and Physics of the USSR Academy of Science. Subsequently they were prepared for press and were published as a separate book. Krylov wrote the introduction and the first part, "The Analytic Theory of Gyroscopes," but the second part, "The Theory of Gyroscopes in Vector Formulation" was written by Krutkov. In a brilliant and concise form this vector formulation presented all the results which had been obtained in the first part (where it had been given in the form of a solution of the Lagrange equations), but a lot of attention and imagination was required for its mastery, since, as has been said already—practically no attention was paid to vector analysis in the programs of our institutions of higher learning in those years. In regard to the method which he chose, Krutkov wrote: "We are proceeding in accord with the behest of Poinsot who said in his famous 'A New Theory on the Rotation of Bodies' (1851): 'Our analysis still shows that it is preferable that everything in it be expressed and be developed in terms of the direct data of the problem, and not in terms of angles and coordinates that are not connected with the nature of the question at all and appear thanks only to the indirect method which is being used for the solution"

VII. A learned opinion of Krutkov's scientific studies has been preserved in Krylov's very extensive archive. It consists of several rough drafts and of separate neatly recopied pages. "Professor Yu. A. Krutkov, Corresponding member of the USSR Academy of Science," we read in this review, "is one of the most outstanding specialists in mechanics and theoretical physics in the USSR. His dissertation on adiabatic invariants, written in 1918, (See[9]—V. F.), was a highly valuable contribution to the atomic theory being created at that time...." "Not to speak of the totally exceptional qualities of his oral exposition, it must be

Krylov's article went into volume IV of the "Matematicheskaya Entsiklopediya" ("Mathematical Encyclopedia") by Felix Klein who had enlisted the collaboration of this outstanding Russian scientist in his encyclopedia; see [18].

*Krutkov's article [23] deals with the contents of that book.

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noted that in his lectures he did not confine himself to expounding results already known, but introduced new methods... In addition to studies in theoretical physics, Yu. A. Krutkov has a series of works on mechanics relating to the rotation of solids. The study of such motion is important for establishing a theory of gyroscopic instruments for various purposes, such as the gyrocompass and gyropilot, which guide a ship along the assigned course automatically; the vertical gyroscope and the directional gyroscope which have come to be the most important fire-control instruments; the Obry instrument that guides a torpedo on its assigned course automatically although it may have been released on another course on account of the arrangement of mines, etc. These instruments are receiving more and more significance for purpose of defense and are being perfected both here and abroad; in order to obtain these improvements, one must beforehand work out the full theory of instruments, the mastery of which was shown by Krutkov in our joint study 'A General Theory of Gyroscopes'.") This opinion was written by Krylov at the time when Krutkov was arrested in 1937 and it is quite obvious that Krylov was guided by a fervent desire to mitigate Krutkov's fate as much as possible. The authority of one of the most prominent scientists in the country helped him achieve this goal and during the years of imprisonment Krutkov was afforded the possibility of working in his specialty. Upon returning to Leningrad he renewed his career at Leningrad University--he began to head the Mechanics Section in the Department of Mathematics and Mechanics. Vladimir Ivanovich Smirnov (who along with Sergeĭ Ivanovich Vavilov and Vladimir Aleksandrovich Fock played a large role in Krutkov's fate and return to work at the University) recalls coming to Krutkov's first lecture after so long a recess. Krutkov was very pale and nervous before it began, but after he had overcome the first difficult minutes, after which, as they say, he "let himself go," the lecture proceeded with great success, and the lecturer was awarded with a burst of applause by his audience.

One again students, graduate students, and doctoral candidates came to Krutkov. In 1949 his new book "Tenzor funktsii naprazheniya i obshchie resheniya v statike teorii uprogosti" (The Tensor of Stress Functions in the Statics of Elasticity Theory[46], appeared. (Its editor was V. A. Fock.) We refer here to a review of this book by G. A. Grinberg, corresponding member of the USSR Academy of Science, who was doing research in the theory of elasticity right at that time, namely the end of the Forties and the beginning of the Fifties. Grinberg thinks that the ideas expressed by Krutkov in this book and the methods developed by him on the basis of these ideas have not been sufficiently appreciated and that they can still exert a considerable influence on the development of the corresponding branch of elasticity theory.

We see that now Krutkov's like was beginning to enter a normal and happy channel. However in 1952 Krutkov began to suffer ill health more and more often. (Back in 1934 in his letters to his sister he had complained of long, lingering pains near his heart.) When he was already in the hospital two weeks before the end, Krutkov learned that a series of special articles which he had worked on over the course of several of the last years of his life, had been awarded a State Prize. He died September 12, 1952.

"Geniuses suggest and formulate theorems; highly talented people prove them"--that is approximately how the aphorism goes that describes various scientists, especially physicists and mathematicians. This is what comes to mind when you think of the role that Krutkov played in science. Through his articles on quantum theory, on adiabatic invariants, and on statistical mechanics, he did a great deal for the clarification and refinement of the basic positions of the theories that were springing up, and in this context his contribution to theoretical physics is very significant. In addition one should cite his original works on mechanics and Brownian motion, on the theory of gyroscopes, on the theory of elasticity, and his organizational services in the very formation of Soviet Physics.

A grateful memory of this prominent scientist must be preserved in the history of physics of our fatherland.

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*This issue of the journal contains articles by I. M. Vinogradov, N. I. Muskhelishvili, A. A. Fridman, G. A. Shaĭn and others.

*To this list let us add four more articles by Krutkov that were published apparently in Issue No. 15 (1923) of Trudy GOI, judging from the covers of other issues of Trudy and from a reference in Kurtkov's own work: [29]

I. Generalization of a Theorem by Larmor, 5 pp.

II. Adiabatic Invariants of the two "Essential Integrals $H = c_1$ and $p_2 = c_2$), 5 pp.

III. Note on the Correlation of a Microcanonical System with a Canonical System, 4 pp.

IV. Note on Adiabatic Invariants of Conditionally-periodic Systems, 2 pp.

Judging from the contents of Issue No. 15, as given on the covers of later issues, all of these short articles were written in German. It should be noted, however, that this issue could not be located in the library of the GOI, in the library of the USSR Academy of Science, nor in the Saltykov–Shchedrin State Public Library. This may be due to the fact that this issue was printed in Berlin.

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Translated by J. S. Bross