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MEMORIES OF MEDVEDEV — A KIND AND GENTLE BEAR

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Historian of mathematics Feodr Andreevich Medvedev died about a year ago (late May ?) at his home in Moscow. He was born on 18 February 1923 and took his post-secondary studies at the Kaluga Pedagogical Institute before beginning his research in history of mathematics in the Department of History of Mathematics of the Institute for History of Science and Technology of the Russian Academy of Sciences in 1955. The exact date of his death is unknown, as he lived alone in his apartment, having lost his wife earlier, and he lay undiscovered for several days before alarmed colleagues from the Institute for History of Science and Technology decided to check on him and broke down the door.

I first became acquainted with the name Medvedev through Ivor Grattan-Guinness's double review in *History and Philosophy of Logic* of Medvedev's «Ранняя история аксиомы выбора» [*Early History of the Axiom of Choice*] and Gregory H. Moore's *Zermelo's Axiom of Choice*, which also appeared in 1982. Both books are very similar, although Medvedev's is more chronologically limited, proceeding in its account only to the end of World War I. It is characteristically generous of Medvedev that when I talked to him in 1987, he expressed to me the opinion that Moore's book was the better of the two. When he made some deprecating remarks about his own work, I said «не говори так!» ("Don't say such a thing!", literally, "Don't talk like that"), and he asked: «Почему?» ("Why?", really meaning "Why not?"). When I met Grattan-Guinness two years later at the International Charles S. Peirce Sesquicentennial Symposium at Harvard University in September 1989, I told him of this exchange, and he replied that he thought this intellectual modesty and generosity to be typical of Medvedev.

Medvedev's name became increasingly familiar to me as I read his papers in *Trudy Inst. Ist. i Estestv. Nauk* and *Ist.-mat. Issled.* Medvedev, besides being the most active worker in history of set theory and related areas such as general function theory and topology, was also the most thorough and systematic, and with the most solid technical interests and expertise. It is not surprising therefore that he should have produced a number of papers directly relating to technical aspects of Cantorian transfinitism. His

1978 paper "Cantor's Theory of Real Numbers" is workmanlike, and provoked remarks by the famous function theorist, the late A.I. Markushevich, in which the latter added to Medvedev's discussions his own considerations about Méray, Heine, and Dedekind on the real line which the former had not discussed. The 1985 paper on "Cantorian Set Theory and Theology" deals with the philosophical aspects of Cantorian transfinitism from the standpoint of mathematics. More recently, however, Medvedev's interests had changed, and included intuitionism, functional analysis and mathematical physics. Writings on these interests included a paper on nonstandard analysis and the history of functional analysis (1987) and another on Giovanni Giorgi and P.A.M. Dirac on δ-functions (1988).

Medvedev's Kandidat dissertation (1958) was on *The First Work in Russia on Set Theory and Theory of Functions of Real Variables*. In 1965, he gave a detailed account of the early history of set theory in his book *The Development of Set theory in the Nineteenth Century*. Here, he examined the connections of the work of Gauss, Steiner, von Staudt, Weierstrass Riemann, De Morgan, Cantor, Dedekind, Peano, and many others in number theory, analysis, algebra, geometry and logic to the development of set theory. This is an elaboration and continuation of his work of 1959 on "The Origins of Set Theory" in the work on trigonometric series, integration theory, and the theory of real numbers and his 1959 work examining some of the first textbooks and monographs on set theory, in particular of Zermelo's 1908 "Untersuchungen über die Grundlagen der Mengenlehre, I", Gerhard Hessenberg's 1906 *Grundbegriffe der Mengenlehre*, and V.L. Nekrasov's 1907 *Structure and Measure of Linear Point Sets.*

The Lebesgue chain, we know, is defined as a collection of intervals such that for each point p of a closed interval $[a, b]$, there corresponds a half-closed subinterval $[p, q)$ such that $p \leq q < b$. The importance of the Lebesgue chain is that it is a mapping of the unit interval into itself, such that $0 < f(x) \leq 1$ and $x < f(x)$, so that any point p is the lower bound of the half-open interval $[p, f(x))$. Thus, the Lebesgue chain allows us to concretize some of the abstract concepts of Cantor's transfinite ordinal arithmetic. Indeed, in "Peano's Functions of a Set" (1965), in which Medvedev considers functions of a set for analysis, it is stressed that Lebesgue already realized the importance of these chains. Also in 1965, Medvedev examined the history of the Lobachevskii-Dirichlet conception of the function. Here, in examining functions of sets of Peano, he concluded that the theory of functions implies set theory.

Decades earlier, in 1904, Pavel Florenskij 1904 gave the first sketches in Russian of Cantor's ideas on infinity. And in the early 1920s, the noted set theorist and topologist Pavel Samuilovich Urysohn (1894-1924) wrote an immense essay on Cantorian set theory, published posthumously in the 1925 and 1926 issues of *Fundamenta Mathematicæ* along with supplementary notes, and a necrology, by his long-time collaborator and friend Pavel Sergeevich Aleksandrov (1896-1983): this was Part I of Urysohn's famous 1925-1926 "Mémoire sur les multiplicités Cantoriennes"; to this was appended

Aleksandrov's [1926] supplementary note, which included references, as was Aleksandrov's 1925 memorial note on Urysohn. Part II of Urysohn's 1927 "Mémoire", entitled "Les lignes Cantoriennes," which considered point set theory as based on Cantor's general set theory, appeared posthumously in the *Journal of the Royal Academy of Sciences of Amsterdam.* It is here that we see the connections between Cantorian set theory and the work in function theory of Fréchet and Lebesgue in virtue of which Medvedev can speak, in his paper on Peano, about the theory of sets of Kolmogorov, and conclude that the theory of functions implies set theory. P.S. Aleksandrov's own work as a historian of mathematics was considered by Medvedev in 1985. Medvedev's historical studies of work in function theory and descriptive set theory is in line with the spirit of work by Lyapunov and Novikov of 1948 describing Soviet contributions to descriptive set theory.

Medvedev's 1978 paper on Cantor's theory of real numbers follows his 1966 study of the early history of the Equivalence Theorem and precedes his two 1982 studies of the history of König's theorem. This is a natural development, and all of these studies are closely related. The Equivalence Theorem, for example, which, as we noted, says that if $S \subseteq S' \subseteq S''$ and S'' and S have the same cardinality, then S'' has the same cardinality as S', is a direct consequence of the Continuum Hypothesis, according to which $\mathbb{R}$ has the cardinality of the second class of numbers.

In a paper of 1977, Medvedev explored some of the early polemics surrounding the axiom of choice and its use; and in his 1980 paper "The Axiom of Choice and Mathematical Analysis," he took pains to illustrate, against the critics of the axiom of choice, the implicit use made of the axiom in analysis, for example in Cantor's theorem on nested sets, and in Peano's use of the axiom in his paper on additive functions. In two papers of 1979, he examined the use which Cantor made of AC and its equivalents; in the second paper of 1979 in particular, he examined Cantor's use of AC in his 1883 work "Über unendliche, lineare Punktmannichfaltigkeiten." Medvedev's 1982 paper "On Two Proofs of the Theorem of Finite Covers" examines Borel's use of AC.

Cantor showed that the cardinality of the set $\mathbb{N}$ of natural numbers (or of any countably infinite set) is $\aleph_0$. Moreover, $\mathbb{N}$ is ordered, so its ordinal is ω_0. Next, Cantor obtained the result that the cardinality of the set of real numbers is $\aleph_1$. Cantor's continnum hypothesis (CH) states that $2^{\aleph_0} = \aleph_1$; and the general continuum hypothesis (GCH) states that $2^{\aleph_\alpha} = \aleph_{\alpha+1}$. Cantor also proved that the set of algebraic reals is well-ordered. Given GCH and the well-ordering of the algebraic reals, it is easy to conjecture that the set of reals can be well-ordered. Cantor did not provide a formal proof, but Zermelo was able to prove that any set can be well-ordered. For the related question of the completeness for real numbers, Medevdev, in his 1981 paper "On the Problem of Completeness in the Theories of Real Numbers" argued that the papers of Cantor, Dedekind, Heine, Kossack, and Méray do not in fact contain the rigorous completeness proofs which they claim to have. In his 1982 papers on the history of König's theorem

—— or more precisely, as Medvedev called it, the Zermelo-König theorem —— he noted that Cantor's continuum problem therefore implies the axiom of choice (AC). In this paper, Medvedev pointed out the ways in which the Zermelo-König result appeared in earlier papers on cardinal arithmetic of Dedekind, König, P.E.B. Jourdain, Zermelo, and Zhegalkin, and he analyzes I.I. Zhegalkin's 1907 work *Transfinite Arithmetic* in which the result was first obtained. Zhegalkin's discovery passed unnoticed by Western logicians until it was 'rediscovered' by Medvedev's work on Zhegalkin. The Zermelo-König theorem states that for cardinal numbers $\mathfrak{m}_t$ and $\mathfrak{n}_t$ and for every t in the set T, if $\mathfrak{m}_t < \mathfrak{n}_t$, then the sum of $\mathfrak{m}_t$'s are smaller than the product of $\mathfrak{n}_t$'s, that is $\Sigma_{t\in T}\ \mathfrak{m}_t < \Pi_{t\in T}\mathfrak{n}_t$. Using a later variant of this result it can be shown that Tychonov's product theorem is equivalent to AC.

We may also note here that Medvedev's discussion of the equivalence theorem is closely bound with his consideration of Cantor's work on CH and AC. The Equivalence Theorem states that if if $S \subseteq S' \subseteq S''$ and S'' and S have the same cardinality, then S'' has the same cardinality as S'. As Medvedev noted in 1966, this is a variant of the Cantor-Schröder-Bernstein theorem (more often simply called the Schröder-Bernstein theorem), according to which $\mathfrak{m} \leq \mathfrak{n}$ and $\mathfrak{m} \geq \mathfrak{n}$ if and only if $\mathfrak{m} = \mathfrak{n}$. By means of the trichotomy principle for cardinals, we have $\mathfrak{m} \leq \mathfrak{n}$ or $\mathfrak{m} \geq \mathfrak{n}$ or $\mathfrak{m} = \mathfrak{n}$. Thus, if both $\mathfrak{m} \leq \mathfrak{n}$ *and* $\mathfrak{m} \geq \mathfrak{n}$, then clearly $\mathfrak{m} = \mathfrak{n}$. But the Trichotomy Principle is equivalent to AC; so the Cantor-Schröder-Bernstein theorem is proven by AC. The Equivalence Theorem is also related to GCH, by the clear result from AC that $\mathfrak{m} < 2^{\mathfrak{m}}$. Medvedev surveys the development of the Equivalence Theorem on cardinal numbers, and considers it, then, in connection with the induction principle, along with the comparability property of cardinals and with impredicative definitions. He remarks on the proof of the Equivalence Theorem by Dedekind in 1887 and on its rediscovery by A. Korselt (1911), Peano (1906), and Zermelo (1908).

AC has of course been the focus of much attention, historical, mathematical, and philosophical; it is not the exclusive concern of Medvedev. More has been written about AC than about most other axioms of set theory, and not merely because of any intrinsic historical interest, but because AC was so controversial, and remains so to this day. This is why it was necessary for Medvedev in 1980 to show the implicit uses of AC in areas of mathematics outside of set theory, such as analysis, which have practical value and therefore would be less amenable to attack from dialectical materialism on ideological-philosophical grounds. Whether one accepts AC or not very often depends upon one's attitude towards transfinitism ——this is very much a philosophical, as well as methodological, question. Thus, we find that AC does not hold in constructive mathematics, whereas the axioms of dependent choice and of countable choice do. We have mentioned Medvedev's consideration of the Equivalence Theorem in connection with the induction principle. Now let us note that, philosophically, rejection of AC is tied to rejection of transfinite induction. For Medvedev, study of AC and related concepts of set theory were not, therefore, mere historical exercises, but vital concerns of set theory. The methodological question is raised for mathematics, of whether to accept transfinite induction or limit the power of one's set theory to finite induction. Moreover, we are faced with the fact that transfinite induction is just a special case of the relative consistency proof. Hence, we cannot obtain a completeness theorem for an infinite arithmetic system, just as Cantor, Dedekind, Heine, Kossack, and Méray, as shown by Medvedev, were unable to provide the rigorous completeness proof for the reals which they each claimed to have provided. This problem is under active research by present-day Russian logicians, such as E.A. Dereviankina. Medvedev's work provides both a historical and a technical basis from which to carry out these current researches. Both AC and consistency and completeness proofs require, as well as arise out of, transfinitism. Methodologically, transfinite induction is related to AC, since AC guarantees the validity of transfinite induction by insuring that, if the first element α of a set A_0 is well-ordered, then so is A'_0, so that any property holds, by downward Löwenheim induction on A'_0, for every β of A'_0. This means that Medvedev's historical work is of vital current interest and import.

In 1985, Medvedev, together with A.N. Kolmogorov and A.P. Yushkevich, published a collection of Russian translations of many of Cantor's most crucial mathematical and philosophical papers in set theory in their book *Georg Cantor, Works in Set Theory*. The biography of Cantor in the 1985 Russian edition of Cantor's work is by Medvedev, while the "Epilogue" which sets the work of Cantor in historical context is by Kolmogorov and Yushkevich.

For all the work on Cantor, Medvedev also reminded us in his work that Cantor did not create set theory singlehandedly. His 1966 paper "Dedekind's Contributions to the Theory of Sets" is such a paper. In this paper, Medvedev cites, as an example, the Cantor-Dedekind correspondence in support of his claim. Some of this correspondence the Medvedev-Kolmogorov-Yushkevich edition of *Georg Cantor, Works in Set Theory*. Medvedev's 1984 paper is also concerned with the interconnections of the work of Cantor and Dedekind in abstract set theory. In his 1966 paper on Dedekind, Medvedev reiterates the claim made in 1965 that all branches of mathematics, not just analysis and function theory, contributed towards the development of set theory. Despite this, most of the focus in history of set theory remains on Cantor. Medvedev in 1970 gave a more general discussion of Dedekind's work, in which he notes Dedekind's contributions to number theory, and in particular his work on the real numbers, on algebraic numbers, on natural numbers and the connections of this work to the development of both set theory and abstract algebra.

In the early 1970s Medvedev wrote a paper on Dedekind (1970) and several works on the history of function theory. Medvedev's more general work on the history of function theory was followed by a more parochial and chronologically specific survey in his 1976 book *The French School of Theory of Functions and Sets on the Border of the*

19th-20th Century, which takes into account, for example, the work of Henri Lebesgue and that of Fréchet and which takes into consideration his work in function theory and the connections between work in real analysis and set theory. The work in function theory and descriptive set theory undertaken by the French mathematicians during this period was seen by Medvedev to be significant not only because of the connections which P.S. Aleksandrov, Urysohn, and Luzin established with their French colleagues, but generally for the development of set theory.

I met Feodr Andreevich on 18 August 1987, during the Eighth International Congress of Logic, Methodology and Philsophy of Science in Moscow (LMPS '87). We were introduced by Aleksei Georgeevich Barabashev, and he had come to meet and talk with me. My first impression of him was that he was anything but what Americans might think bear-like (in Russian, *medved'* means bear), but more like the good-natured bears of Russian folktales; I remember him as a diminutive gray-haired elderly man with a kindly, helpful and dignified demeanor, and I immediately thought of him as an old-world gentleman, of the pre-revolutionary variety, the kind one might expect to encounter on an idyllic Sunday afternoon stroll through a park in a Chekhov play, perhaps seated on a park bench, in a mellow, beneficent mood, placidly watching as middle-aged couples dance a stately "Old-world Quadrille" while their children play their quiet games — scenes that probably never existed in any past reality and exist today, but only on a stage, either in a Chekhov play (in which "Uncle Vanya" and a slightly younger, not-yet-emeritus and therefore not yet grouchy or claustrophobic Professor Serebryakov, their families and friends, have been transported from the countryside to Moscow or some provincial capital), or at a performance by the Moyseev Dance Company. We had a pleasant talk, on Cantor and Russell, and Yanovskaya; he was especially interested in the plan I outlined to him of writing a history of mathematical logic in the Soviet Union. It doubtless put him in mind of his teacher, Sof'ya Aleksandrovna Yanovskaya (1896-1966), who had written two such studies, one very brief survey (1948), just a few more than fifty pages, on thirty years of "Foundations of Mathematics and Mathematical Logic" in the Soviet Union, the second (1959) a lengthy survey, just over 100 pages, of forty years of "Mathematical Logic and Foundations of Mathematics" in the Soviet Union, covering the period 1947-1957.

Medvedev was one of Yanovskaya's older students, and he remembered her primarily as an organizer. In a paper about Yanovskaya published in *Studies in Soviet Thought* (1973), J.M. Bocheński recounted an incident surrounding a paper which he once wrote for the obscure and privately published *Festgabe an die Katholiken Schweizern* (1954); the paper in question, "Spitzfindigkeit", was a sardonic and humorous mock of classical arguments against formal logic. In the paper on Yanovskaya, Bocheński wrote that no one took his "Spitzfindigkeit" paper seriously, except Yanovskaya, who replied with a scholarly discussion of some thirty or more pages, in her 1962 work on Descartes' geometry and mathematical method — no one except Yanovskaya and the "stern reviewer" of the *Journal of Symbolic Logic*, namely my own teacher Jean van Heijenoort.

At the Moscow logic congress, I told this story to Medvedev and to Barabashev. Medvedev told me that this information on the spot favorably altered his opinion of Yanovskaya: whereas he used to view Yanovskaya primarily as an administrator rather than as a teacher, he declared that this information caused now him to take her efforts as a historian of mathematics more seriously, and to re-evaluate as well the unfavorable opinion of Bocheński which he had formed from Yanovskaya's treatment of him. Interestingly, Barabashev told me later that Medvedev repeated the story to some of his colleagues, and it made the rounds of Moscow's historians of mathematics, to S.S. Demidov, who had himself been one of Yanovskaya's later students, and Demidov in turn passed it on to Barabashev. The story thus became in some small way a part of the folklore of Moscow University, where Yanovskaya had taught (four days earlier, on the 14th, Mikhail Ivanovich Panov kindly showed me the very classroom in which Yanovskaya conducted her classes).

Before the Russian revolution of 1917, both Yanovskaya and founder of combinatory logic Moses Schönfinkel (Mojse Isa'evich Shejnfinkel'; d. 1942) had been mathematics students of Samuil Osipovich Shatunovskij (1859–1929) at Odessa University in the Ukraine. Had Shatunovskij's two most famous and successful students known each other in those days? I asked Medvedev, who replied that neither he nor anyone else had ever thought of asking Yanovskaya while she was alive, and so no on knew the answer to that question.

I saw Medvedev later on the 18th as well; he had come specifically to hear my afternoon talk on "Russell's Problems with the Calculus," sitting next to me and talking until it came my time to speak, and leaving at the end of my talk. In my talk I used then-unpublished, and so to the audience unknown, materials from the Russell archives dating from 1896-1899 to outline Russell's early criticisms of infinitesimal analysis, both the Newtonian and Leibnizian variety, and of real analysis as presented by Weierstrass. This was Russell's neo-Hegelian period, and I was therefore able to note some similarities between Russell's complaints about calculus and those rendered by Karl Marx in his *Mathematical Manuscripts* (especially when the differential is treated first as an infinitesimally small quantity and then as 0). This must also have struck a responsive chord, perhaps putting Medvedev in mind of the "Preface" which Yanovskaya had written for her Russian translation of the *Manuscripts*.

While in Moscow, I received numerous gifts of books and papers from colleagues. Medvedev presented me with a copy of his «Ранняя история аксиомы выбора» in memory of our first conversation. Before I left Moscow, he also presented me with a copy of Георг Кантор, «Труды по теорий множеств» [Georg Cantor, *Works in Set Theory*] (1985) which he, Kolmogorov, and Yushkevich compiled and translated. This particular book caused a minor international incident, but at the same time graphically illustrated the meaning of *perestroika*. Because of the large number of books and papers I had received while in Moscow, it was impractical to attempt to carry them, and I therefore resolved to send them home by mail. With the assistance of Barabashev, we spent a

Sunday afternoon in the attempt, riding a tram from the Main Post Office, through a run-down factory district where ancient monasteries were being repaired in preparation for the millennial celebration of the founding of the Russian Orthodox Church in 988, and finally arriving at Moscow's International Post Office, where the books were wrapped, packed, labelled for shipping, and postage affixed. The postal worker took especial exception to our attempt to send the Cantor book out of the country, arguing that these scientific materials could not be sent abroad, even though we explained to her that all of the papers in the book were already a hundred years old and that they were simply Russian translations of works that had been previously published. Our logic must have finally convinced her ——or our desperation and exasperation must have shown, because at last she agreed that she would "do what she could." In the end, to my very great joy, all of the packages (but one, which had been lost in the mail) arrived safely, including both «Ранняя история аксиомы выбора» and Кантор, «Труды по теорий множеств».

After I returned to the United States, Medvedev and I exchanged correspondence and publications, although with monotonically decreasing frequency as time passed. One project which we discussed was the preparation of a collection of his more important studies in the history of set theory for publication in English. But this project has so far not gone beyond the proposal stage.

In the words of his student and friend A.G. Barabashev, Medvedev was a "brilliant researcher" and he will be missed. Together, the *troyka* (trio) of Yanovskaya, Nikolai Ivanovich Styazhkin (1932–1986), and Medvedev were the principal modern pioneers of history of mathematical logic in the Soviet Union. Like the *troyka* (a kind of rough-hewn wooden cart drawn by a three-abreast team of horses) in Gogol's *Dead Souls*, they "dashed along, inspired by God," "a lightening flash sent down from heaven;" and "now all that can be seen in the distance is something raising dust and boring through the air."

Some Publications of F.A. Medvedev:

1958. Первые работы в России по теории множеств и теории функции действительного переменного, Кандидат. диссерт., Инст. Истории Естест. и Техники, АН-СССР.

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1963. Подготовка теоретико-множественных и теоретико-функциональных исследований в России, Инст. Ист. Естест. и Техники, «Очерки истории математики и механики: сборник статей» (Москва: АН-СССР), С. 45-66.

1965. Функции множеств у Д. Пеано, Историко-матемтатический исследования 16, С. 311-324.

1965. Развитие теории множеств в XIX веке, Москва, «Наука».

1966. Вкладе Дедекинда в теорию множеств, История и методология естественных наук 5, С. 192-199.

1966. Ранняя история теоремы эквивалентности, Ист.-мат. исслед. 17, С. 229-246.

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1974. Развитие понятия интеграла, Москва, «Наука».

1975. Очерки истории теории функций действительного переменного, Москва, «Наука». English translation by Roger Cooke as *Scenes from the history of real functions* (Basel, Birkhäuser Verlag, 1991); reviewed by Angus E. Taylor, AMS Bulletin (n.s.). 28 (1993), 360-367.

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1977. *Le commencement de la polémique sur l'axiome de Zermelo*, XVth International Congress of the history of science. Edinburgh, 1977. Papers by Soviet Scientists, section III: Mathematics and Mechanics since 1600 (Moscow, Nauka), 48–59.

1978. О канторовской теории действительных чисел, Ист.-мат. исслед. 23, С. 56-70, 357.

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1982. Ранняя история аксиомы выбора, Москва, «Наука».

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1982. *Über ein Theorem von G. König*, NTM-Schriftenr. Gesch. Naturwiss. Tech. und Medizin 19, nr. 2, 15-20. (Translation of the previous.)

1982. О двых доказательсвтах теоремы о конечном покрытии, Ист. и методол. естеств. наук 29, С. 86-90.

1983. Теории абстрактных множеств Кантора и Дедекинда, Семиотика и информатика (Москва, ВИНИТИ), С. 45-80.

1984. О теориях абстрктных множеств Кантора и Дедекинда, Семиотика и информатика 22, С. 45-80.

1985. О трудах П.С. Александрова по истории математики, Ист.-мат. исслед. 29, С. 113-136.

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1985. В соредакторстве с А.Н. Коломогоровым и А.П. Юшкевичым, Георг Кантор, Труды по теории множеств, Москва, Наука.

1985. В соавторстве с А.Н. Коломогоровым и А.П. Юшкевичым, Посолвие, А.Н. Колмогоров, А.Ф. Медведев, А.П. Юшкевич (ред.), Ф.А. Медведев и А.П. Юшкевич (перев.), Георг Кантор, Труды по теории множеств (Москва, «Наука»), С. 373-381.

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