Jarník's Notes of the Lecture Course Allgemeine Idealtheorie by B. L. van der Waerden (Göttingen 1927/1928)

Vojtěch Jarník (1897-1970)

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VOJTĚCH JARNÍK
(1897 – 1970)[1]

Childhood and studies

Vojtěch Jarník was born in Prague on December 22, 1897. His father Jan Urban Jarník (1848–1923), a professor of Romance philology at Charles University, was a well-known authority on French, Romanian and Albanian languages, poetry and folklore.

Jarník studied at *c. k. vyšší reálné gymnasium*, located in Ječná street in the center of Prague quite close to where the Jarníks lived. After his graduation, he entered the Philosophical Faculty of Charles University as a part-time student. According Austro-Hungarian academic law he was ineligible to attend classes on a regular full-time basis until he had satisfied the University's Latin requirement, which he did three semesters later.[2] On January 17, 1917, now a regular student at the University, he was exempted from military service and so could continue his studies uninterrupted by the war.

He was at Charles University from 1915 to 1919 attending lectures in mathematics, physics, philosophy, psychology, chemistry and Czech and German literature. He was taught mathematics by Karel Petr (1868–1950), Bohuslav Hostinský (1884–1951), Karel Rychlík (1885–1968), Jan Sobotka (1862–1931), Bohumil Bydžovský (1880–1969) and Václav Láska (1862–1943), and physics by Bohumil Kučera (1874–1921), Václav Posejpal (1874–1935), Vladimír Václav Heinrich (1884–1965) and František Záviška (1879–1945).[3] During his studies at the University as well as afterwards Jarník was influenced by the mathematician Karel Petr.[4]

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[1] The text is a modification of the chapter in [BeNe] and it is taken with the permission of the coauthor.

[2] He passed the Latin examination on March 21, 1917, at the famous grammar school, Akademické gymnasium, situated in Štěpánská street in Prague.

[3] It is interesting to mention that Jarník, during regular studies at Charles University, had 98 hours of physics and 113 hours of mathematics, more than half of which were taught by Petr.

[4] After his studies at Charles University, Karel Petr was a professor of mathematics and physics at secondary schools in the Czech lands and Moravia. In 1904, he was appointed a professor of mathematics at Charles University and he held the post until his retirement in 1938. In 1920–1921, he was the first Dean of the Faculty of Sciences of Charles University and in 1925–1926 he was the Rector of Charles University. He was interested in number theory, algebraic forms, mathematical analysis and numerical methods. He wrote Czech textbooks on differential and integral calculus *Počet integrální* [Integral Calculus] (1915, 1931), *Počet diferenciální* [Differential Calculus] (1923) and *O differenciálních rovnicích* [On

Early mathematical work

Immediately after completing his studies in 1919, Jarník started working as an assistant to Jan Vojtěch (1879–1953), professor of the Technical University in Brno. However, he spent only two academic years there and in 1921 returned to Prague and became an assistant to Petr. Under Petr's supervision he wrote his dissertation *O kořenech funkcí Besselových* [On the Zeros of Bessel Functions] which he successfully defended in the academic year 1920/1921.[5] He received the title RNDr. after final examinations at the then newly founded Faculty of Sciences of Charles University in 1921.

Petr continued to influence Jarník's studies in mathematical analysis and number theory. At the beginning of the twenties when Petr was finishing his textbook *Počet differenciální* [Differential Calculus],[6] Jarník helped him with the proof-reading and even contributed some improvements to the text.

Jarník's extraordinary mathematical erudition was firmly demonstrated in his paper *O funkci Bolzanově* [On the Function of Bolzano] (1922)[7] in which he examined in detail a recently discovered manuscript of Bernard Bolzano (1781–1848), dating from the 1830s.[8] Jarník proved, among other things, that Bolzano's function is in fact the oldest example of a continuous nowhere differentiable function; this might have been the stimulus for Jarník's future interest in real function theory. Jarník's assessment of the work *Functionenlehre*,[9] which had been discovered among the papers in Bolzano's inheritance, was of great importance.[10]

Differential Equations] (1911). In the years 1905–1920, he was the Editor-in-Chief of the mathematical section of *Časopis pro pěstování mathematiky a fysiky* [Journal for Cultivation of Mathematics and Physics] and he succeeded in raising its level.

[5] There is no copy left in the Archives of Charles University. For some information, see Jarník's article *O kořenech funkcí Besselových* [On the Zeros of Bessel Functions], Rozpravy České akademie pro vědy, slovesnost a umění, II. třída, 29(1920), No. 28, 6 pages.

[6] K. Petr: *Počet differenciální* (*část analytická*), Jednota československých mathematiků a fysiků, Praha, 1923, xvi + 466 pages.

[7] Časopis pro pěstování matematiky a fysiky 51(1922), pp. 248–264.

[8] Bernard Bolzano was a mathematician, philosopher and theologian. From 1805 to 1820, he was the head of the Department of Religious History at the Philosophical Faculty in Prague. Because he criticised the Austrian authorities and church, as well as the political and social system, he was retired and spent many years under the police control. As a consequence of his activities he disappeared from teaching, publishing and public life. Only few of his mathematical and philosophical works were published during his life. Many of them remained in manuscripts and were not easy to read; they were finally studied in the twentieth century. About his life and work see *The Bernard Bolzano Pages at the FAE*: http://www.sbg.ac.at/php/bolzano [9.6.2019].

[9] B. Bolzano: *Functionenlehre*, edition "Spisy Bernarda Bolzana", Vol. 1, Královská česká společnost nauk, Praha, 1930, xx + 184 + 24 + vi pages.

[10] Later Jarník gave probably one of the best qualified evaluation of Bolzano's results in analysis. See V. Jarník: *Bolzano and the Foundations of Mathematical Analysis*, Society of Czechoslovak Mathematicians and Physicists, Praha, 1981, 89 pages + 8 pictures. (Translated by J. Jarník from the Czech version: *Bolzano a základy matematické analýzy*, Jednota československých matematiků a fyziků, Praha, 1981, 81 pages + 8 pictures.) Bolzano's works are available in the *Czech Digital Mathematics Library* (http://www.dml.cz [10.10.2019]).

Studies in Göttingen

Petr recognized early Jarník's outstanding mathematical talent and gave him full support. In 1923, Jarník left Prague and travelled to Göttingen where he studied and worked until February 1925. He was apparently most influenced by Edmund Landau (1877–1938),[11] an outstanding specialist in mathematical analysis and number theory. (It should be mentioned that Jarník had studied analytic number theory and Landau's well-known works before his visit to Göttingen.) Once there, he regularly attended the lectures of E. Landau and E. Noether,[12] which were well received and inspiring for younger mathematicians. He also took part in their seminars and was in close touch with their students.

In the academic year 1927/1928, Jarník paid his second long-term visit to Göttingen and continued his collaboration with Landau.[13] He also regularly visited the lectures of K. Grandjot,[14] P.S. Aleksandrov,[15] B.L. van der Waer-

[11] Edmund Landau studied at the University in Munich and then at the University in Berlin where he graduated (1899). After obtaining his degree (1901) he lectured in Berlin. In 1909, he moved to Göttingen where he was named an ordinary professor of mathematics. He had to stop his lectures at the University in Göttingen in November 1933 because of the disgusting boycott led by the young student Oswald Teichmüller, fanatic Nazi and member of the SA. After his resignation Landau moved to Berlin where he died on February 19, 1938. He was interested in analytic number theory, theory of functions of complex variables etc. His monographs *Handbuch der Lehre von der Verteilung der Primzahlen* (1909), *Darstellung und Begründung einiger neuerer Ergebnisse der Funktionentheorie* (1916), *Vorlesungen über Zahlentheorie* (1927) and *Grundlagen der Analysis* (1930) inspired many young mathematicians. For more information on Landau see [Ch], [HH], [L], [Kp] and [S2]. See also [S1] and [Se].

[12] From the archival sources it is certain that he chose Noether's lectures – *Invariantentheorie* (summer semester 1923/1924), *Körpertheorie* (summer semester 1923/1924), *Gruppentheorie II* (winter semester 1924/1925) and *Hyperkomplexe Zahlen und Gruppencharaktere* (winter semester 1927/1928).

[13] Jarník's second stay was supported by the International Education Board from which he received a scholarship to spend one academic year in Göttingen to work on number theory with Landau. Jarník was strongly recommended and supported by Petr. For more information see [SSr1], pp. 293.

[14] Karl Grandjot (1900–1979) studied at the University in Göttingen and he graduated there with the thesis *Über das absoluten Konvergenzproblem der Dirichletschen Reihen* (1922). From 1925 to 1929, he was a private docent in Göttingen; he then moved to Chile and became an ordinary professor of mathematics. He taught at the Pedagogical Institute of the University of Santiago de Chile until 1965 when he was retired. He was interested in analysis and geometry of numbers. Jarník chose Grandjot's lectures – *Algebra II* (winter semester 1927/28) and *Galoissche Theorie* (winter semester 1927/1928).

[15] Pavel Sergeevich Aleksandrov (1896–1982) studied mathematics under Vyacheslaw Vassilievich Stepanov (1889–1950), Nikolai Nikolaevich Luzin (1883–1950), and Dmitri Fedorovich Egorov (1869–1931) at the University in Moscow (1913–1916). Then he shortly taught at the University in Smolensk (1920–1921). From 1921, he lectured at the University in Moscow where he gave lectures on several interesting and modern topics (functions of real variable, topology, Galois theory etc.). In the academic year 1923/1924, he studied at the Mathematical Institut of the University in Göttingen. From 1924 until 1932, he went to Germany mostly every summer, lectured there and collaborated with Richard Courant (1888–1972), Felix Hausdorff (1868–1942), David Hilbert (1862–1943), Heinrich

den[16] and E. Landau.[17] It should be noted that Landau deeply influenced Jarník's professional career and without any doubt he was Jarník's second important "mentor". Throughout Landau's life, they were in the close touch and often collaborated together.[18]

From the second half of the twenties, Jarník was interested in number theory (especially in problems of lattice points) and theory of real functions. He wrote his articles in the Czech, German and French languages and published them in Czech or German journals.

Thanks to his studies in Göttingen and his conversations with German mathematicians, and under their influence, Jarník finished more than ten works, some of which were published in Mathematische Zeitschrift,[19] Mathematische

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Hopf (1894–1971), Emmy Amalie Noether (1882–1935) and other German mathematicians. A large part of the academic year 1927/1928 he spent at Princeton in the USA where he collaborated with Solomon Lefschetz (1884–1972), Oswald Veblen (1880–1960) and James Waddell Alexander (1888–1971). Aleksandrov's first outstanding results are connected with topology and theory of functions of real variables. In many papers from the 1920s and 1930s he developed the basis of topology, homology and cohomology theory, theory of dimension, theory of bicompact spaces. In the 1940s he discovered the ingredients of an exact sequence of the kernel of a homomorphism, and later he worked on the theory of continuous mappings of topological spaces. Some of his works are also connected with geometry, functional analysis, mathematical logic, foundations and history of mathematics. For more information see [AKMO], [BeNe] and [ZD]. V. Jarník chose Aleksandrov's lecture – *Punktmengen und reelle Funktionen* (summer semester 1927/1928).

[16] Jarník chose van der Waerden's lectures – *Allgemeine Idealtheorie* (winter semester 1927/1928) and *Algebraische Zahlen* (summer semester 1927/1928).

[17] Jarník chose Landau's lecture on higher analysis (summer semester 1927/1928).

[18] See for example V. Jarník, E. Landau: *Untersuchungen über einen van der Corputschen Satz*, Mathematische Zeitschrift 39(1935), pp. 745–767 (the article is dated: Vojtěch Jarník in Prag und Edmund Landau in Berlin. [Eingegangen am 8. November 1934.]); V. Jarník: *Edmund Landau* †, Časopis pro pěstování matematiky a fysiky 67(1938), pp. D215–D216; Jarník's reviews – *E. Landau. Vorlesungen über Zahlentheorie I–III*, Časopis pro pěstování matematiky a fysiky 57(1927), pp. 62–63, *E. Landau. Grundlagen der Analysis*, *E. Landau. Einführung in die Differentialrechnung und Integralrechnung*, ibid., 64(1935), pp. D91–D92 and *E. Landau. Über einige neuere Fortschritte der additiven Zahlentheorie, J.M. Vinogradov, Novyj metod v analitičeskoj teorii čísel*, ibid., pp. D303–D306. It should be mentioned that Jarník had a bound collection of the most of all Landau's reprints.

[19] *Über die Gitterpunkte auf konvexen Kurven*, Mathematische Zeitschrift 24(1926), pp. 500–518 (the article is dated: Vojtěch Jarník in Göttingen [Eingegangen an 18. Januar 1925.] and it is finished with these words: *Ich möchte diese Gelegenheit nicht vorübergehen lasse, ohne dem Herrn Prof. E. Landau in Göttingen und dem Herrn Prof. K. Petr in Prag für ihre mannigfache Anregung, ihre wertvollen Winke und ihr Interesse an meinen Arbeiten meinen Dank auszusprechen.*); *Über bedingt konvergente Reihen*, ibid., 24(1926), pp. 715–732 (the article is dated: Vojtěch Jarník in Göttingen [Eingegangen am 31. 1. 1925.]); *Über die Gitterpunkte auf homothetischen Kurven*, ibid., 26(1927), pp. 445–459 (the article is dated: Vojtěch Jarník in Prag [Eingegangen am 6. April 1927.]); *Umordnungen von bedingt konvergenten Reihen*, ibid., 28(1928), pp. 360–371 (the article is dated: Vojtěch Jarník in Prag [Eingegangen am 8. Juni 1927.]); *Über Gitterpunkte in mehrdimensionalen Ellipsoiden*, ibid., 27(1928), pp. 154–160 (the article is dated: Vojtěch Jarník in Prag [Eingegangen am 4. Mai 1927.]); *Über Gitterpunkte in mehrdimensionalen Ellipsoiden* (*Zweite Mitteilung*), ibid., 28(1928), pp. 311–316 (the article is dated: Vojtěch Jarník in Göttingen [Göttingen, den 14. Dezember 1927.]).

Annalen[20] and Annali di matematica pura ed applicata.[21]

At the end of the twenties and during the thirties, Jarník continued in his study of number theory and Diophantine approximations. He published his results in Mathematische Zeitschrift, Monatshefte für Mathematik und Physik, Tôhoku Mathematical Journal as well as in Czech journals.[22]

Professor in Prague

From 1921, Jarník was continuously, excepting that period of Nazi occupation when Czech institutions of higher education were forcibly closed, a member of the staff of Charles University. After his return from the first German visit in 1925, Jarník defended in 1925 his *Habilitation* thesis (devoted to lattice points).[23] On December 19, 1925, he became an associate professor (docent) and he started to incorporate modern mathematical methods and theories in his lectures. His first regular lecture after his *Habilitation* (1925/1926) concerned the Lebesgue integral.[24] The following year, together with his colleagues, he opened a special seminar for students named *Discussions on newer directions in mathematics*. In 1929, Jarník was appointed an extraordinary professor and six years later he was appointed a full professor of Charles University. The decade before the Second World War was probably the most propitious time for his scientific work and pedagogical activities.

In 1931, Jarník added an appendix to Petr's book *Počet integrální* [Integral Calculus], which is the very first Czech text on naive set theory, titled *Úvod do theorie množství* [Introduction to Set Theory].[25] He also reread and corrected Petr's manuscript.

Later, in 1936, he wrote an appendix *O derivovaných číslech funkcí jedné reálné proměnné* [On Dini's Derivates of Functions of One Real Variable] in which he summarized his new results on differentiability of typical continuous functions. The appendix appeared in Čech's book *Bodové množiny* [Point Sets] (1936).[26]

From the end of the twenties, Jarník intended to write newer and more modern Czech textbooks on real analysis, and in the late thirties he started

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[20] *Über Gitterpunkte in mehrdimensionalen Ellipsoiden*, Mathematische Annalen 100(1928), pp. 699–721 (the article is dated: Göttingen, den 21. November 1927 [Eingegangen am 22. 11. 1927.]); *Über Gitterpunkte in mehrdimensionalen Ellipsoiden. Zweite Abhandlung*, ibid., 101(1929), pp. 136–146 (the article is dated: Göttingen, den 27. Januar 1928 [Eingegangen am 1. 2. 1928.]).

[21] K. Grandjot, E. Landau, J.E. Littlewood, V. Jarník: *Bestimmung einer absoluten Konstanten aus der Theorie der trigonometrischen Reihen*, Annali di matematica pura ed applicata, 6(1928–1929), Serie 4, 7 pages.

[22] For more information see the bibliography of Jarník's scientific works published in [N2].

[23] See V. Jarník: *O mřížových bodech v rovině* [On Lattice Points in Plane], Rozpravy České akademie pro vědy, slovesnost a umění, II. třída, 33(1926), No. 36, 23 pages.

[24] The lecture notes of the course have unfortunately not been found.

[25] Appendix to K. Petr: *Počet integrální*, 2nd edition, Praha, 1931, pp. 655–725.

[26] Appendix to E. Čech: *Bodové množiny*, Praha, 1936, pp. 245–265.

publishing his books on differential and integral calculus. The first was titled *Úvod do integrálního počtu* [Introduction to the Integral Calculus].[27] In addition, during the war he had worked on books which later appeared in four volumes under the names *Diferenciální počet I, II* [Differential Calculus I, II] and *Integrální počet I, II* [Integral Calculus I, II].[28] These textbooks, of monographic character, influenced generations of Czech mathematicians. The four-volume work concluded with two texts, *Diferenciální rovnice v reálném oboru* [Differential Equations in Real Domain][29] and *Matematická analýza pro 3. semestr* [Mathematical Analysis for the 3rd Semester of Studies][30] and the book *Diferenciální rovnice v komplexním oboru* [Differential Equations in Complex Domain].[31] While the *Diferenciální počet I* and *Integrální počet I* have an introductory character, the second two volumes *Diferenciální počet II* and *Integrální počet II* were written in the real analysis monographic style and contain some unique sections, including a concise and very instructive chapter on computational methods of integral calculus in $\mathbb{R}^n$. Unfortunately, they were published only in the Czech language, and thus unavailable to most foreign students.

In 1926, Jarník was elected a member of *Česká královská společnost nauk* [Bohemian Royal Society of Science]. In 1934, he became an extraordinary member and in 1946 a regular member of *Česká akademie pro vědy a umění* [Czech Academy of Sciences and Arts]. From 1916, he was also a member of *Jednota českých matematiků a fysiků* (later Jednota československých matematiků a fysiků) [Union of Czech Mathematicians and Physicists] (later Union of Czechoslovak Mathematicians and Physicists), and for several decades he was active in its Central Committee and later was named an honourary member of *Jednota* (1962). From 1935 to 1950, he was Editor-in-Chief of the mathematical section of *Časopis pro pěstování matematiky a fyziky* [Journal for Cultivation of Mathematics and Physics] and succeeded in raising the journal to international level.

After the war

From 1945, Jarník continued teaching mathematics at Charles University. He also held numerous positions there. From 1947–1948, he was the Dean of

[27] Praha, 1938, 168 pages.

[28] *Diferenciální počet I*, Praha, 1st edition, 1946, 448 pages (2nd edition, 1951, 448 pages, 3rd edition, 1953, 449 pages, 4th edition, 1955, 451 pages, 5th edition, 1963, 390 pages, 6th edition, 1974, 390 pages); *Diferenciální počet II*, Praha, 1st edition, 1953, 595 pages (2nd edition, 1956, 609 pages, 3rd edition, 1976, 688 pages); *Integrální počet I*, Praha, 1st edition, 1948, 324 pages (2nd edition, 1954, 295 pages, 3rd edition, 1956, 299 pages, 4th edition, 1963, 243 pages, 5th edition, 1984, 243 pages); *Integrální počet II*, Praha, 1st edition, 1955, 760 pages (2nd edition, 1976, 760 pages).

[29] On the basis of the lectures of Prof. V. Jarník prepared by Vladimír Petrův, Učební texty vysokých škol, Státní pedagogické nakladatelství, Praha, 1963, offset, 245 pages.

[30] Učební texty vysokých škol, Státní pedagogické nakladatelství, Praha, 1965, rotaprint, 246 pages (2nd edition, 1984, 246 pages).

[31] Academia, Praha, 1975, 283 pages.

the Faculty of Sciences of Charles University, from 1948–1949 the Vice-Dean at the same Faculty, from 1950–1953 the Vice-Rector of Charles University, and from 1958–1960 the Dean of the Faculty of Mathematics and Physics of Charles University. In spite of his ever increasing administrative responsibilities, Jarník assiduously devoted himself to his teaching. All his lectures were perfectly thought out, scrupulously prepared, read with equanimity and pedagogical mastership. Without doubt he was one of the best teachers at Charles University in the twentieth century. Both through his scientific and teaching activities he influenced several generations of Czech and Slovak mathematicians. Jarník retired from the University in 1968. He died in Prague on September 22, 1970.

Mathematical and scientific achievements

During his long career Jarník wrote about 90 scientific works. Almost a third of them are devoted to problems of lattice points, another third to Diophantine approximations and geometry of numbers, about twenty papers concern the theory of real functions.[32]

Jarník was an expert in traditional fields of mathematical analysis and also one of the first Czech mathematicians who mastered set theory and topology, measure theory and the theory of the integral. He was probably the first Czech mathematician whose scientific results received a wide and lasting international response and continue to be cited to the present day.

In 1952, he was among the founding members of Czechoslovak Academy of Sciences. In 1952–1955, he was the chairman of its Mathematics-Physics Section and in 1964–1966 the chairman of the Scientific Board for Mathematics of the Academy. For extraordinary scientific results he was awarded the State Prize (1952), the Order of Work (1967) and the Order of Republic (1967). At the end of his pedagogical career, he became "Doctor Honoris Causa" (Charles University, 1968) and he obtained the Silver Medal for Merit in Sciences and Humanity (Czechoslovak Academy of Sciences, 1968). For more than twenty years, he was a member of the editorial board of *Czechoslovak Mathematical Journal* and the journal *Acta Arithmetica*, which specialized in number theory.

For more information about Jarník's life and mathematical results see [BeNe], [KS], [KV], [K1]–[K3], [KN1]–[KN3], [N1], [N2], [Ne1], [Ne2], [NSch], [R], [Re], [Rk], [Sz], [W1] and [W2].

[32] Jarník's influential contributions to Diophantine approximations, lattice point theory, number theory, real analysis as well as graph theory are analysed in [N2], where the complete bibliography of Jarník's publications is provided.

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