Applied Nonlinear Analysis

In honor of the 70th birthday of Professor Jindřich Nečas

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PREFACE

This book is meant as a present to honor Professor J. Nečas on the occasion of his 70th birthday.

It collects refereed contributions from sixty-one mathematicians from eleven countries. They cover many different areas of research related to the work of Professor Nečas, including Navier-Stokes equations, nonlinear elasticity, non-Newtonian fluids, regularity of solutions of parabolic and elliptic problems, operator theory and numerical methods.

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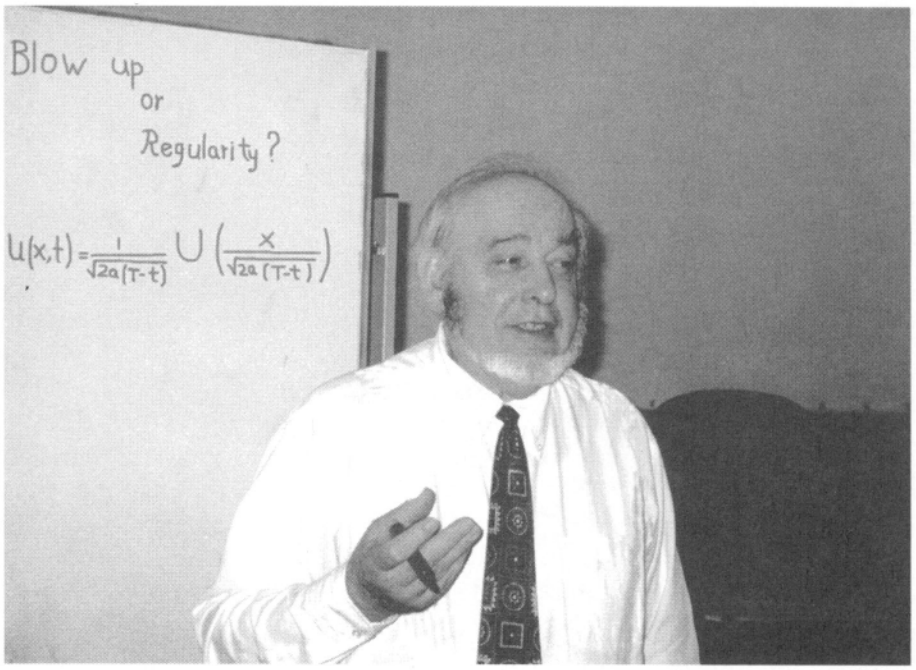
On behalf of the editors

ADÉLIA SEQUEIRA



JINDŘICH NEČAS

JINDŘICH NEČAS

Jindřich Nečas, honored by the Order of Merit of the Czech Republic by Václav Havel, President of the Czech Republic, on the October 28, 1998, Professor Emeritus of Mathematics at the Charles University in Prague, Presidential Research Professor at the Northern Illinois University and Doctor Honoris Causa at the Technical University of Dresden, has been enriching the Czech and world mathematics with his new ideas in the areas of partial differential equations, nonlinear functional analysis and applications of the both disciplines in continuum mechanics and hydrodynamics for more than forty years.

Born in Prague in December 14, 1929, Jindřich Nečas spent his youth in the nearby town of Mělník. He studied mathematics at the Faculty of Sciences of the Charles University in Prague between 1948-1952. After a short period at the Faculty of Civil Engineering of the Czech Technical University he joined the Mathematical Institute of the Czechoslovak Academy of Sciences where he headed the Department of Partial Differential Equations. Since 1977 he has been a member of the staff of the Faculty of Mathematics and Physics of the Charles University being in 1967-1971 the head of the Department of Mathematical Analysis, for many years the head of the Department of Mathematical Modelling and an active and distinguished member of the Scientific Council of the Faculty.

Let us go back to Nečas' first steps in mathematical research. He was the first PhD. student of I. Babuška, whom he still recalls with gratitude. As one of his first serious tasks he cooperated in the preparation of the pioneering monograph *Mathematical Methods of the Theory of Plane*

Elasticity by Babuška, Rektorys and Vyčichlo. It was mechanics which naturally directed him to applications of mathematics.

This period ended in 1957 with his defence of the dissertation *Solution of the Biharmonic Problem for Convex Polygons.* His interests gradually shifted to the functional analytic methods of solutions to partial differential equations. It was again I. Babuška who oriented him in this direction, introduced him to S. L. Sobolev and arranged his trip to Italy. His visits to Italy and France, where he got acquainted with the renowned schools of M. Picone, G. Fichera, E. Magenes and J. L. Lions deeply influenced the second period of Nečas' career.

Here we can find the fundamental contributions of Nečas to the linear theory: Rellich's identities and inequalities made it possible to prove the solvability of a wide class of boundary value problems for generalized data. They are important also for the application of the finite element method. This period culminated with the monograph *Les méthodes directes en théorie des équations elliptiques.* It became a standard reference book and found its way into the world of mathematical literature. We have only to regret that it has never been reedited (and translated into English). Its originality and richness of ideas was more than sufficient for J. Nečas to receive the Doctor of Science degree in 1966.

Without exaggeration, we can consider him the founder of the Czechoslovak school of modern methods of investigation of both boundary and initial value problems for partial differential equations. An excellent teacher, he influenced many students by his enthusiasm, never ceasing work in mathematics, organizing lectures and seminars and supervising many students to their diploma and Ph.D. thesis. Let us mention here two series of Summer Schools—one devoted to nonlinear partial differential equations and second interested in the recent results connected with Navier-Stokes equations. Both of them have had fundamental significance for the development of these areas.

While giving his monograph the final touch, J. Nečas already worked on another important research project. He studied and promoted the methods of solving nonlinear problems, and helped numerous young Czechoslovak mathematicians to start their careers in this domain. He also organized many international events and—last but not least—achieved many important results himself.

Nonlinear differential equations naturally lead to the study of nonlinear functional analysis and thus the monograph *Spectral Analysis of Nonlinear Operators* appeared in 1973. Among the many outstanding results let us mention the infinite dimensional version of Sard's theorem for analytic functionals which makes it possible to prove denumerability

of the spectrum of a nonlinear operator. Theorems of the type of Fredholm's alternative represent another leading topic. The choice of the subject was extremely well-timed and many successors were appearing soon after the book had been published. This interest has not ceased till now and has resulted in deep and exact conditions of solvability of nonlinear boundary value problems. Svatopluk Fučík, who appeared as one of the co-authors of the monograph, together with Jan Kadlec, who worked primarily on problems characteristic for the previous period, and with younger Rudolf Švarc—were among the most talented and promising of Nečas' students. It is to be deeply regretted that the premature death of all three prevented them from gaining the kind of international fame as that of their teacher.

The period of nonlinearities, describing stationary phenomena, reached its top in the monograph *Introduction to the Theory of Nonlinear Elliptic Equations.* Before giving account of the next period, we must not omit one direction of his interest, namely, the problem of regularity of solutions to partial differential equations. If there is a leitmotif that can be heard through all of Nečas' work, then it is exactly this problem, closely connected to the solution of Hilbert's nineteenth problem.

In 1967 Nečas published his crucial work in this field, solving the problem of regularity of generalized solutions of elliptic equations of arbitrarily high order with nonlinear growth in a plane domain. His results allow a generalization for solutions to elliptic systems. In 1968 E. De Giorgi, E. Giusti and M. Miranda published counterexamples convincingly demonstrating that analogous theorems on regularity for systems fail to hold in space dimension greater then two. The series of papers by Nečas devoted to regularity in more dimensional domains can be divided into two groups. One of them can be characterized by the effort to find conditions guaranteeing regularity of weak solutions. Here an important result is an equivalent characterization of elliptic systems whose weak solutions are regular. This characterization is based on theorems of Liouville's type. The fact that Nečas' method can be applied to the study of regularity of solutions of both elliptic and parabolic systems demonstrates its general character. During this period Nečas collaborated also with many mathematicians (M. Giaquinta, B. Kawohl, J. Naumann). The other group of papers consists of those that aim at a deeper study of singularities of systems. J. Nečas is the author of numerous examples and counterexamples which help to map the situation.

In the next period, Nečas resumed his study of continuum mechanics. Again we can distinguish two fundamental groups of his interest. The former concerns the mechanics of elasto-plastic bodies. J. Nečas

is the co-author of monographs *Mathematical Theory of Elastic and Elasto-plastic bodies: An Introduction* (with I. Hlaváček), *Solutions of Variational Inequalities in Mechanics* (with I. Hlaváček, J. Haslinger a J. Lovíšek). Let us also mention the theory of elastoplastic bodies admitting plastic flow and reinforcement, as well as the theory of contact problems with friction. It was J. Polášek who initiated Nečas' interest in transonic flow where he achieved remarkable results by using the method of entropic compactification and the method of viscosity. These results raised deep interest of the mathematical community, Nečas published the monograph *Écoulement de fluide, compacité par entropie.* In 1986 M. Padula presented her proof of the global existence of non-steady isothermal compressible fluids. This article led Nečas and Šilhavý to introduce a model of multipolar fluids satisfying the laws of thermodynamics. In this model the higher order stress tensor and its dependence on higher order velocity gradients are taking into account, the well-posedness of the model, the natural and logical construction of fundamental laws, and deep existence results were settled.

The most recent considerations are devoted to classical incompressible fluids, namely, to the Navier-Stokes fluids and to the power-law fluids. Essentially new existence, uniquenesss and regularity results are given for space periodic problem and for Dirichlet boundary value problem. Large time behaviour of solutions is analysed via the concept of short trajectories. A comprehensive survey of these results can be found in *Weak and Measure Valued Solutions to Evolutionary PDE's* (with J. Málek, M. Rokyta and M. Růžička).

The central theme in the mathematical theory of the Navier-Stokes fluids, i.e. the question of global existence of uniquely determined solution, has also become central in the research activities of J. Nečas in the past five years. Attention has been given to the proof that the possibility of constructing a singular solution in the self-similar form proposed by J. Leray in 1934, is excluded for the Cauchy problem, J. Nečas concentrates his energy to find the way of generalization of this result and to the resolution of the initial problem as well as to the study of influence of boundary conditions on the behaviour of the fluid described by Navier-Stokes equations.

A significant feature of Nečas' scientific work is his intensive and inspiring collaboration with many mathematicians ranging from the youngest to well-known and experienced colleagues from all over the world. Among them (without trying to get a complete list) we would like to mention: H. Bellout, F. Bloom, Ph. Ciarlet, A. Doktor, M. Feistauer, A. Friedman, M. Giaquinta, K. Gröger, Ch.P. Gupta, W. Hao, I. Hlaváček, R. Kodnár, V. Kondratiev, Y.C. Kwong, A. Lehtonen,

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We tried to collect some of the most important contributions of J. Nečas and to display the breadth of his interests and strivings, his encouragement of young people, his never ending enthusiasm, his deep and lively interest in mathematics. All these features of his personality have attracted students everywhere he has been working and have influenced many mathematicians.

OLDŘICH JOHN, JOSEF MÁLEK, JANA STARÁ

THE MOST SIGNIFICANT WORKS OF PROF. J. NEČAS

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