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NEWS AND NOTICES

IN MEMORIAM JINDŘICH NEČAS

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Jindřich Nečas, a leading Czech mathematician and a world-class researcher in partial differential equations (PDEs), would have celebrated his 75th birthday on December 14, 2004. He passed away on December 6, 2002.

He will be remembered not only for his mathematics, but also for his friendly, engaging personality and the energy and enthusiasm which characterized his activities. He attracted many young talented mathematicians to PDEs and the Czech PDE community owes much to his natural leadership.

High points of his research include

(1) his contributions to boundary regularity theory for linear systems, where, in the 1960s, he pioneered the use of what is now often called the Rellich-Nečas identity;

(2) his contributions to regularity theory of variational integrals, such as his 1977 solution of a long-standing question directly related to Hilbert's 19th problem;

(3) his contributions to mathematical theory of the Navier-Stokes equations, including his 1995 solution of an important problem raised in a classical 1934 paper by J. Leray.

His many interests outside mathematics and physics included music, history, and philosophy.

Jindřich Nečas was born in Prague on December 14, 1929. He grew up in the town of Mělník, and he always liked to come back there. In the years 1948–1952, he studied

As Mathematica Bohemica suggested that the paper about Jindřich Nečas' life and work should contain a description of his contribution to mathematics as detailed as possible, the authors decided that each part of this article should be prepared by persons working in the corresponding area. Thus the part on mechanics was written by I. Hlaváček, regularity and nonlinear functional analysis by O. John, V. Šverák and J. Stará, the beginnings and linear theory by A. Kufner, fluid mechanics by J. Málek, V. Šverák and Š. Nečasová who also supplied biographical data and a list of last Jindřich Nečas' publications. The authors would like to thank M. Feistauer for his comments concerning Jindřich Nečas' influence to numerical analysis and Mitchell Luskin and Jiří Jarník for their assistance.

at the Faculty of Natural Sciences of the Charles University in Prague. After a short stay at the Czech Technical University (ČVUT), he started his graduate studies at the Mathematical Institute of the Czechoslovak Academy of Sciences (MÚ ČSAV) under the supervision of Professor Ivo Babuška. He obtained his PhD in 1957. In 1960 he became head of a new department at MÚ ČSAV. He was promoted to the academic rank of Docent in 1964, and in 1966 he obtained the highest scientific degree in Czechoslovakia at that time, the Doctor of Sciences. In 1967 his well-known monograph "Les méthodes directes en théorie des équations elliptiques" was published. In the same year he became head of the Department of Mathematical Analysis at the Faculty of Mathematics and Physics of Charles University (MFF UK). In 1977 he permanently left his MÚ ČSAV position for a position at the MFF UK. However, he was not promoted to the richly deserved academic rank of University Professor until 1990, due to the politics of the post-1968 era in Czechoslovakia. During the last years of his life he divided his time between Prague, where he was Professor Emeritus, and the University of Northern Illinois, DeKalb, where he held a position of Distinguished Research Professor.

His visits abroad were very important for his scientific career. His mathematics and his outgoing personality won him many friends in mathematics departments around the world.

He received many honors, including the Order of Merit of the Czech Republic, which he was awarded by President Václav Havel on October 28, 1998. The Technical University of Dresden awarded him the Doctorate Honoris Causa. Preparation of his Doctor Honoris Causa nomination at the University of Bayreuth was interrupted by his passing away.

First steps

At the beginning of his first job in the Department of PDEs at MÚ ČSAV, J. Nečas worked in the group of Professor Ivo Babuška on problems in continuum mechanics. He was part of the team working on mathematical models used in the construction of the large Orlík Dam on the Vltava River. This work was motivated by practical engineering problems, but it also stimulated new theoretical results. J. Nečas' life-long interest in continuum mechanics and, more generally, in applications of mathematics, can be traced back to this period. His first papers [C1], [C2] as well as papers [C3], [C4] on applications of the Laplace transform were inspired by the work on the "Orlík" project.

Also, his dissertation concerning the biharmonic problem for convex polyhedra was stimulated by the problems related to the Orlík period. He defended the dissertation in 1957 and published the results in [C5], [C6] and [C8]. In these papers, he solved the biharmonic problem in an infinite wedge by means of integral transforms.

Linear theory

Soon after finishing his dissertation, J. Nečas got interested in modern methods and the unifying themes of his work on linear problems the following topics became:

(i) The variational (Hilbert-space) approach to boundary value problems. (The term "direct approach" is also often used.)

(ii) Methods applicable to systems of equations (i.e., equations with vector-valued unknowns) and equations of higher order.

(iii) Regularity of weak solutions in domains with limited smoothness of the boundary, such as Lipschitz domains.

The motivation for his work on (ii) and (iii) (which goes back to his Orlík period) is that, for Jindřich Nečas, one of the basic prototypical equations was Lamé's system of linear elasticity on a Lipschitz domain, a situation naturally coming up in many applications.[1]

Given (ii) and (iii), Nečas' interest in the variational approach is very natural: the approach is very general and not very sensitive to various regularity assumptions or the vector-valued nature of the solutions.

The variational approach consists of re-formulating the boundary value problem as an abstract equation in a suitable Hilbert space. The abstract equation can usually be solved by general Hilbert-space results (such as the Riesz Representation Theorem or its generalization, the Lax-Milgram Lemma). The solution obtained in this way is called a weak solution, and often one can set things up so that weak solutions are unique. This step is often quite easy. The second, usually more difficult step, is to prove that the weak solution is in fact a classical solution. In most problems this amounts to proving that the solution is sufficiently regular.[2]

The variational approach is closely related to the theory of Sobolev spaces. These function spaces and methods related to their applications were studied in I. Babuška's department intensively. The basic literature used was Sobolev's fundamental monograph [S]. Jindřich Nečas, showing his independence, soon started using a new approach to Sobolev space theory introduced by E. Gagliardo.

[1] It is worth mentioning that even today many basic questions related to boundary regularity for this problem remain unsolved, in spite of intensive research in the area. We recall that boundary regularity for elliptic systems in smooth domains was dealt with in a more or less definitive form in [ADN].

[2] A typical example of a regularity result is Weyl's Lemma (1940), saying that a weakly harmonic function is in fact smooth, and hence analytic.

An important role in J. Nečas' work on boundary regularity of weak solutions is played by Rellich's identity and its generalizations. In the simplest case of the Laplace operator, the Rellich identity reads

$$
\begin{aligned}
(1)\quad &\int_{\partial\Omega} (h_k\delta_{ij} - h_i\delta_{kj} - h_j\delta_{ik}) \frac{\partial v}{\partial x_i}\frac{\partial v}{\partial x_j} n_k \,\mathrm{d}S \\
&\qquad = \int_\Omega \Big(\frac{\partial h_k}{\partial x_k}\delta_{ij} - \frac{\partial h_i}{\partial x_k}\delta_{kj} - \frac{\partial h_j}{\partial x_k}\delta_{ik}\Big) \frac{\partial v}{\partial x_i}\frac{\partial v}{\partial x_j}\,\mathrm{d}x - 2\int_\Omega h_i \frac{\partial v}{\partial x_i}(\Delta v)\,\mathrm{d}x,
\end{aligned}
$$

where $v \in W^{2,2}(\Omega)$, $h_i \in C^\infty(\overline{\Omega})$, $i = 1, \ldots, n$. J. Nečas independently re-discovered this identity, generalized it, and used it to great effect to study boundary regularity. For example, by integration by parts one can get from (1) that for the equation $-\Delta u = f$ in a bounded Lipschitz domain Ω with boundary condition $u = 0$, the normal derivative is square integrable on the boundary. Using a duality argument, one can use it to solve the Dirichlet problem for boundary data which are merely in L^2. These ideas appear in [C11].

J. Nečas later generalized these results in [C14] and [C24]. This work became well-known and today the term Rellich-Nečas identity is often used in this connection. The research in boundary regularity for Lipschitz domains continues to be a very active research area.

Paper [C28] contains another well-known contribution of J. Nečas. It concerns equivalence of various Sobolev norms in Lipschitz domains. The simplest case is represented by the inequality

$$
\|u - c\|_{L^2(\Omega)} \leqslant C\|\nabla u\|_{W^{-1,2}(\Omega)}
$$

where c is the average of u over Ω and Ω is a bounded Lipschitz domain. This can be considered a significant generalization of the classical Poincaré inequality. Inequalities of this form have turned out to be very useful in many situations.

In paper [C18], J. Nečas used weighted Sobolev spaces. He always emphasized the importance of choosing the function spaces which are best fitted to the boundary value problem at hand. He inspired several young mathematicians to take up research on deeper properties of function spaces. Some of them started a seminar dedicated to this branch of mathematics. This was the beginning of the well-known Prague school of weighted Sobolev spaces, which continues to be very active. Its activities include Spring Schools organized regularly every five years since 1978. (See, for example, [P1] and [P2] for the proceedings of the first and the last one, respectively.)

In the paper [C17] from 1962, J. Nečas introduced an important class of domains on which Sobolev spaces have "good properties". Without giving here the full definition of his "domains of type $\mathfrak{N}$", we just remark that they have a close connection to

Lipschitz domains and domains with the cone property. In the paper [C17] he also proved the existence of "regularized distance from the boundary", which is a function $\sigma\colon C^\infty(\Omega)\cap C(\overline{\Omega})\to\mathbb{R}$ equivalent to $\operatorname{dist}(x,\partial\Omega)$ such that

$$|D^\alpha\sigma|\leqslant C\sigma^{1-|\alpha|}.$$

(Later this result was proved for general domains, see for example [ST] or [TR].)

A culmination of J. Nečas' research on linear problems was his 1967 monograph [A1]. The book originated as J. Nečas' lecture notes [B2] published by MÚ ČSAV as a mimeographed text in 1962–1963. Together with giving an up-to-date introduction to direct methods, the book also contains most of J. Nečas' important results on linear equations. The book aged well, and even today it can be considered one of the best textbooks on direct methods. J. Nečas had written the book in his beloved French. Despite the fact that an English translation has not appeared, the book remains one of the most frequently cited mathematical works by a Czech author.

Regularity for nonlinear equations

A significant part of J. Nečas' work in regularity for nonlinear problems is closely related to classical questions going back to Hilbert's 19th and 20th problems. These concern existence and regularity of functions minimizing (under suitable conditions) variational integrals of the form

$$\int_\Omega F(x,u,\nabla u)\,\mathrm{d}x \tag{2}$$

and their higher-order analogues. J. Nečas started to actively work on these problems around 1965. One of the factors which turned his attention in this direction was a series of lectures by F. E. Browder at a summer school in Montreal held in 1965.

J. Nečas' first important result in this field, published in [C33], can be viewed as a highly nontrivial generalization of a famous result of C. B. Morrey from 1938. Morrey proved full regularity for minimizers of (2) in dimension 2 (under appropriate assumptions). In [C33], J. Nečas generalized this result to a large class of functionals depending on higher-order derivatives. His basic tool was a higher order version of a well-known linear $L^{2+\varepsilon}$-estimate due to N. G. Meyers [MEY], which was also proved in [C33]. Nečas' method of proof has found applications in other situations, for example in regularity problems concerning stationary solutions of certain fluid-dynamics models.

An important milestone in the study of regularity for integrals (2) in dimensions higher than two is the famous 1957 result of E. De Giorgi and J. Nash that, under appropriate assumptions, minimizers of (2) are smooth in the case of a scalar unknown function u. (Various important issues, such as optimal assumptions concerning the dependence of F on u, were clarified later by Ladyzhenskaya and Uraltseva.) These works left open the case of vector-valued unknown functions u. The scalar case is proved by an estimate for solutions of linear equations with measurable coefficients. In 1968, E. De Giorgi and V. Mazja independently constructed examples showing that the critical estimate may fail for the corresponding linear equations with vector-valued unknowns. These examples were later refined by E. Guisti and M. Miranda. However, the original problem of regularity of minimizers of (2) remained open until it was settled by J. Nečas in 1977. Nečas showed that in dimensions five and higher one can construct analytic functions F which do not depend on x and u, are uniformly convex in ∇u, have bounded second derivatives, and the integral (2) admits singular minimizers. We remark that the convexity of F guarantees uniqueness of solutions to natural boundary value problems in the class of weak solutions. It also implies that weak solutions can be identified with minimizers.

Nečas' counter-example remains as astonishing today as it was when it first appeared. Further results related to this problem can be found in [C103], [C172], [MA], [SOU], [SJ]. Many basic questions concerning minimizers of (2) for vector-valued u have remained open. For example, there are no known examples of non-smooth minimizers of functionals (2) for functions u mapping a three dimensional domain into $\mathbb{R}^3$ (under appropriate assumptions on F, of course). For some recent developments see for example [SY] and [MS].

In 1979, J. Nečas together with M. Giaquinta pointed out (in [C96]) an interesting connection between regularity of nonlinear elliptic systems and a Liouville-type condition. For example, in the context of the variational integral (2) with $F(x, u, \nabla u) = F(\nabla u)$, the connection is that the regularity of minimizers of (2) is equivalent, modulo technicalities, to the absence of nontrivial global Lipschitz solutions of the corresponding Euler-Lagrange equation. (Theorems which are conceptually similar appeared first in the theory of minimal surfaces.)

The Liouville condition can be hard to check. Nevertheless, the theorem is important from the conceptual point of view. Also, it was used by J. Nečas, I. Netuka and P. L. Lions to give new proofs of regularity results of K. Uhlenbeck for $F(x, u, \nabla u) = f(|\nabla u|)$ (see [C112]), and J. Nečas used it to give a different proof of regularity results of A. I. Koshelev addressing the case when $\nabla u \to F(x, u, \nabla u)$ is not too far from $|\nabla u|^2$. Many basic problems related to these ideas have remained open.

For a short period of time, J. Nečas also paid attention to regularity for nonlinear parabolic systems. In this area his contribution cannot be overlooked, either. In 1991, he studied with V. Šverák a problem of regularity of weak solutions of the system

$$\frac{\partial u}{\partial t} = \operatorname{div}(A(\nabla u)), \quad u = (u_1(z), u_2(z), \dots, u_N(z)), \quad z = (x_1, x_2 \dots x_n, t)$$

where A is a uniformly monotone mapping.[3]

In [C151], which soon became well-known among specialists, Hölder continuity of weak solutions was proved for $n \leqslant 4$ and Hölder continuity of the gradient was proved for $n \leqslant 2$ (implying full regularity in that case).

The method of proof was based on a nontrivial generalization of a well-known linear $L^{2+\varepsilon}$ estimate of N. G. Meyers [MEY] to the parabolic case. The new linear parabolic estimate enabled the authors to move the time derivative to the right-hand side and treat the system by known elliptic techniques.

We remark that it still seems to be an open problem whether, for $n = 2$, one can improve the linear $L^{2+\varepsilon}$ estimate to a Hölder estimate. (This would immediately give full regularity for the nonlinear problem.) It is known that this cannot work for $n = 3$, due to elliptic counter-examples.

Nonlinear functional analysis

J. Nečas started working on nonlinear problems in the second half of the 1960s. In this area he was essentially influenced by F. Browder and J. Leray.

Nečas was one of the main organizers of a series of memorable summer schools on nonlinear problems. We recall at least the following:

—Richterovy Boudy in Krkonoše Mountains in 1966, with J. Leray, M. M. Vajnberg, R. Finn, E. Giusti and G. DaPrato;

—Tupadly 1969, with E. Heinz, W. Jäger, R. Payne and E. Giusti;

—Babylon 1971, with Melvyn S. Berger, Marion S. Berger, G. Prodi, S. Spagnolo, E. S. Citlanadze, H. Triebel and A. Pultr;

—Podhradí 1973, with G. Anger, V. Barbu, H. Brézis, S. Dümmel, J. Král, N. S. Kružkov and I. Vrkoč.

One of Nečas' main interests in this period was nonlinear functional analysis, especially the spectral theory for nonlinear operators. The monograph [A2] (written with S. Fučík, J. Souček and V. Souček) contains many new results in this area.

The authors consider equations of the form

$$\lambda T(u) - S(u) = f \tag{3}$$

[3] When A merely satisfies the Legendre-Hadamard condition, regularity can completely fail even for solutions independent of t, see [MS].

in a Banach space, where T, S are a-homogeneous odd operators satisfying additional assumptions. Roughly speaking, T behaves as the identity and S is continuous and compact. Equation (3) can then be considered a deformation of the familiar case when T is the identity and S is linear and compact. For the linear case, one way of understanding the classical results concerning (3) is to view the situation in topological terms, such as Leray-Schauder degree, Ljusternik-Shnirelman category, and min-max principles for critical points of functionals on spheres or projective spaces.

In [A2], such topological methods are applied to the nonlinear equation (3) and generalizations of well-known linear results are obtained. For example, a nonlinear version of the Fredholm Alternative Theorem is proved.

Another very interesting result proved in [A2] is an estimate from above of the number of critical points for a class of functionals on Banach spaces. The estimate is based on a generalization of the Morse-Sard theorem to an infinite-dimensional setting, for functionals which are real analytic. The general theory was applied by the authors to a variety of problems for ODEs, PDEs, integral and integro-differential equations.

Since the late 1960s, J. Nečas also did significant work on variational inequalities. This work is discussed in the next section.

In 1983, the monograph [A6] on nonlinear elliptic problems was published, with a second edition in 1986. This book offers an exposition of results in nonlinear functional analysis as well as the regularity theory for nonlinear elliptic systems (discussed in the section Regularity for nonlinear equations). It provides an excellent introduction to these topics.

Mechanics of solids and fluids

Jindřich Nečas loved continuum mechanics. One might probably say that equations of elasticity and fluid mechanics were always on his mind, one way or another.

Mechanics of solids

In 1967, J. Nečas founded the Continuum Mechanics Seminar which attracted a wide audience from Charles University, Czech Technical University, and various institutes of the Czech Academy of Sciences. The audience would typically include students, mathematicians, and engineers. He also lectured on continuum mechanics at the Faculty of Mathematics and Physics of Charles University. These lectures, together with the seminar, were the starting point of Nečas' next succesful book [A4], written with I. Hlaváček. The book contains many original results of Nečas and his collaborators.

Among J. Nečas' favorite topics were unilateral problems in elasticity. These can be modelled by variational inequalities. This is another area where Nečas made important contributions. Together with I. Hlaváček, J. Haslinger and J. Lovíšek he wrote the monograph [A5]. Besides providing an excellent introduction to the subject, it also gives an exposition of original results of Nečas and his collaborators. Of these we should mention at least [C100], where subtle existence results for a model of quasistatic unilateral contact with Coulomb friction are proved, and [C76], where semicoercive unilateral contact problems are discussed and solved. Monograph [A5] later appeared in Russian ([A7]) and English ([A9]).

Jindřich Nečas also made important contributions to the mathematical analysis of models describing the yielding of plastic materials. He proved existence and uniqueness of solutions for models of perfectly plastic bodies and models with isotropic or kinematic hardening. (The penalty method proved to be a very effective tool here.)

He enthusiastically embraced the 1977 existence theory of J. Ball, and together with P. G. Ciarlet studied its extensions to unilateral contact problems (see [C120], [C122], and [C123]).

He studied the dynamics of elastoplastic bodies and proved existence and uniqueness for the corresponding PDEs in [C95]. Later, he turned his attention to nonlinear thermoelasticity ([C143], [C147], [C140]).

In [C143], he studied the problem of hardening in the framework of problems with moving boundary. In [C142], [C156] he analyzed viscoelastic materials and incompressible multipolar fluids.

We must also mention the contributions of J. Nečas to numerical methods suitable for problems in solid mechanics. His proofs of important theoretical results were often based on methods that suggested a good numerical approximation. Kačanov's (secant modules) method ([C65]) with its applications in the nonlinear theory of plastic deformations ([C117]) and Galerkin's method ([A11]) are good examples.

Although Nečas' work in continuum mechanics concentrated mostly on nonlinear problems, he also made important contributions to linear theory. For example, papers [C44], [C45] give a simple algebraic criterion which is equivalent to a coercivity condition for quite general systems of linear PDEs. This result generalizes Korn's inequality known from linear elasticity and can be used to obtain ellipticity for other boundary value problems arising in applications.

Fluid Mechanics

Nečas started working on the equations of fluid mechanics at the beginning of the 1980s. At that time, his attention turned to problems surrounding models of transonic flow. Discussions with J. Polášek in Prague and R. Glowinski and O. Pironneau in Paris played an important role in motivating this work. Nečas studied Glowinski's and Pironneau's proposal in [GP] to use entropy conditions to avoid non-physical solutions of transonic flow models. Results of these investigations are reported in monograph [A10]. A short overview can be found in the book [FE].

Nečas was well aware of the drawbacks of various transonic flow models and started working on the fundamental equations of fluid mechanics in the second half of the 1980s. These equations are notoriously difficult.[4]

In a joint work with M. Šilhavý, J. Nečas systematically studied the possibilities of introducing higher order viscosities which are compatible with basic principles of thermodynamics and frame indifference. In [C150], Nečas and Šilhavý gave a classification of these models. Paper [C138] contains existence and regularity theory for higher-order viscosity models.

Nečas' best-known result in fluid mechanics is probably the paper [C171] which concerns the question of existence of self-similar singular solutions of the classical 3d incompressible Navier-Stokes equations. The question was posed in the famous 1934 paper by J. Leray [LE] which laid the foundations of the mathematical theory of the Navier-Stokes equations. Leray noticed that possible formation of singularities from smooth data in 3d Navier-Stokes equations is compatible with all mathematical properties of the equations known at the time. In fact, he realized that the known properties could not even rule out singularities of the form

$$u(t,x) = \frac{1}{\sqrt{T-t}} U\Big(\frac{x}{\sqrt{T-t}}\Big).$$

These can be thought of as the simplest possible singularities which are mathematically compatible with every property of the Navier-Stokes equations known prior to [C171]. In particular, such singularities are compatible with energy dissipation due to viscosity; they are also compatible with all regularity results which can be proved by perturbation techniques. (Examples of such results include the Ladyzhenskaya-Serrin-Prodi condition and the regularity criteria in the well-known papers by Caffarelli, Kohn and Nirenberg and Sheffer.)

In [C171], self-similar singularities were ruled out by using a new maximum principle hidden in the equations for U. It is perhaps appropriate to quote from a letter which J. Leray wrote to J. Nečas and his co-authors in 1996 after receiving the paper.

...En 1934 j'avais prouvé qu'en dimension spatiale 3, pour Navier-Stokes, le problème de Cauchy sans bord possède toujours au moins une solution, régulière ou

[4] Recently, a leading researcher in mathematical fluid mechanics wrote, adapting a Winston Churchill line: "...The Reynolds equations are still a riddle. They are based on the Navier-Stokes equations, which are still a mystery. The Navier-Stokes equations are a viscous regularization of the Euler equations, which are still an enigma. Turbulence is a riddle wrapped in a mystery inside an enigma" [P. Constantin, CIME lecture notes, 2003].

non; (si elle est régulière, elle est unique; elle est régulière en dimension spatiale 2). Je croyais avoir trouvé, en dimension spatiale 3, un moyen de construire, peut-être, une solution non régulière "self-similar". Votre note et votre texte plus détaillé réussissent à prouver très ingénieusement qu'une telle solution "self-similar" n'existe pas. Je vous en félicite vivement.

J'ai longuement réfléchi, après votre lettre, à ma question de 1934: pour Navier-Stokes la solution du problème de Cauchy peut-elle être non-régulière? A mon grand regret il est sage que je cesse d'y penser. Henri Lebesgue me l'avait conseillé dès 1935!

An important extension of results in [C171] can be found in a paper by T. P. Tsai [TS].[5]

J. Nečas was also very interested in the problem of singularity formation for solutions of Euler's equations. The paper [C180] studies numerical evidence for finite-time blow-up in Euler's equations. Another interesting contribution to the theory of Euler's equations is [C184].

Finally, we would like to mention at least one more result obtained by applying regularity techniques to fluids with shear-dependent viscosity. O. A. Ladyzhenskaya (see [LA]) initiated the study of models for incompressible fluids with viscosities ν of the type

$$\nu(|D|^2) = \nu_0 + \nu_1 |D|^{r-2}\,, \qquad \nu_0, \nu_1 > 0, \tag{4}$$

and showed the existence of global-in-time weak solutions to the corresponding evolutionary 3d model for $r \geqslant \frac{11}{5}$. Given that for the classical 3d Navier-Stokes equations ($\nu_1 = 0$) such a solution exists, one expects that solutions to models with viscosities of the form (4) should exist at least for $r \geqslant 2$. The gap between the two conditions for r was removed (and additional results proved) in [C160], [C162], [A11] for the spatially periodic problem, and in [C178] for no-slip boundary conditions. Proofs of existence of weak solutions in this context usually rest on a compactness result. In the above papers, the necessary compactness result is deduced from the condition

$$\int_0^T \frac{\|\nabla^2 v^\varepsilon(t)\|_2^2}{(1 + \|\nabla v^\varepsilon(t)\|_2^2)^\lambda}\,\mathrm{d}t \leqslant C \quad \text{(uniformly w.r.t. } \varepsilon) \tag{5}$$

where v^ε is a suitable approximate solution.

[5] The problem of regularity of solutions for the incompressible 3d Navier-Stokes equations is one of the seven Millenium Problems named by the Clay Mathematics Institute, which is offering a monetary prize for their solutions. See http://www.claymath.org/millennium/.

Nečas' deep experience in regularity theory for nonlinear elliptic and parabolic systems played a crucial role in derivation of (5).

J. Nečas' leadership and his concern for opening opportunities to young scientists were very important for starting the series of Spring Schools on Fluid Mechanics at Paseky nad Jizerou. He was, together with J. Málek and M. Rokyta, one of the regular organizers. The Schools have been very successful, as can be seen from the distinguished list of lecturers and the large numbers of both foreign and domestic participants.

When discussing Jindřich Nečas' work in mechanics and other applications, we must also emphasize his close relations with the Numerical Analysis community. Nečas was always interested in practical issues arising in computations based on models he studied from the theoretical perspective. Some of his theoretical ideas helped in designing effective numerical algorithms. He had many friends and collaborators among both Czech and foreign numerical analysts. His work on the variational approach to PDEs has had a significant impact on the Czech finite element community.

Final words

Jindřich Nečas was an outstanding mathematician, one of the founders of the modern school of PDEs in Prague. His gift for inspiring people helped many to start their scientific careers. His optimism and enthusiasm for science will be remembered by all who met him, and his work will continue to influence mathematical research in many ways. He will be deeply missed.

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