

# Nonlinear Diffusion Equations and Their Equilibrium States II

Edited by W.-M. Ni, L. A. Peletier,  
J. Serrin

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# Nonlinear Diffusion Equations

**Zhuoqun Wu**



## Nonlinear Diffusion Equations:

**Nonlinear Diffusion Equations** Zhuoqun Wu, 2001 Nonlinear diffusion equations an important class of parabolic equations come from a variety of diffusion phenomena which appear widely in nature They are suggested as mathematical models of physical problems in many fields such as filtration phase transition biochemistry and dynamics of biological groups In many cases the equations possess degeneracy or singularity The appearance of degeneracy or singularity makes the study more involved and challenging Many new ideas and methods have been developed to overcome the special difficulties caused by the degeneracy and singularity which enrich the theory of partial differential equations This book provides a comprehensive presentation of the basic problems main results and typical methods for nonlinear diffusion equations with degeneracy Some results for equations with singularity are touched upon Contents Newtonian Filtration Equations Existence and Uniqueness of Solutions One Dimensional Case Existence and Uniqueness of Solutions Higher Dimensional Case Regularity of Solutions One Dimensional Case Regularity of Solutions Higher Dimensional Case Properties of the Free Boundary One Dimensional Case Properties of the Free Boundary Higher Dimensional Case Initial Trace of Solutions Other Problems Non Newtonian Filtration Equations Existence of Solutions Harnack Inequality and Initial Trace of Solutions Regularity of Solutions Uniqueness of Solutions Properties of the Free Boundary Other Problems General Quasilinear Equations of Second Order Weakly Degenerate Equations in One Dimension Weakly Degenerate Equations in Higher Dimension Strongly Degenerate Equations in One Dimension Degenerate Equations in Higher Dimension without Terms of Lower Order General Strongly Degenerate Equations in Higher Dimension Classes BV and BV x Nonlinear Diffusion Equations of Higher Order Similarity Solutions of a Fourth Order Equation Equations with Double Degeneracy CahnOCohilliard Equation with Constant Mobility CahnOCohilliard Equations with Positive Concentration Dependent Mobility Thin Film Equation CahnOCohilliard Equation with Degenerate Mobility Readership Researchers lecturers and graduate students in the fields of analysis and differential equations mathematical physics and fluid mechanics *Nonlinear Diffusion Equations and Their Equilibrium States*, 3 N.G Lloyd, M.G. Ni, L.A. Peletier, J. Serrin, 2012-12-06 Nonlinear diffusion equations have held a prominent place in the theory of partial differential equations both for the challenging and deep mathematical questions posed by such equations and the important role they play in many areas of science and technology Examples of current interest are biological and chemical pattern formation semiconductor design environmental problems such as solute transport in groundwater flow phase transitions and combustion theory Central to the theory is the equation  $U_t = \Delta u + f(u)$  Here  $\Delta$  denotes the  $n$  dimensional Laplacian  $f$  and  $u$  are given functions and the solution is defined on some domain  $\Omega \times [0, T]$  in space time Fundamental questions concern the existence uniqueness and regularity of solutions the existence of interfaces or free boundaries the question as to whether or not the solution can be continued for all time the asymptotic behavior both in time and space and the development of singularities for instance when the solution ceases to

exist after finite time either through extinction or through blow up

**Semigroup Approach To Nonlinear Diffusion Equations** Viorel Barbu, 2021-09-23 This book is concerned with functional methods nonlinear semigroups of contractions nonlinear  $m$  accretive operators and variational techniques in the theory of nonlinear partial differential equations of elliptic and parabolic type In particular applications to the existence theory of nonlinear parabolic equations nonlinear Fokker Planck equations phase transition and free boundary problems are presented in details Emphasis is put on functional methods in partial differential equations PDE and less on specific results

*Smoothing and Decay Estimates for Nonlinear Diffusion Equations* Juan Luis Vázquez, 2006-08-03 This text is concerned with the quantitative aspects of the theory of nonlinear diffusion equations equations which can be seen as nonlinear variations of the classical heat equation They appear as mathematical models in different branches of Physics Chemistry Biology and Engineering and are also relevant in differential geometry and relativistic physics Much of the modern theory of such equations is based on estimates and functional analysis Concentrating on a class of equations with nonlinearities of power type that lead to degenerate or singular parabolicity equations of porous medium type the aim of this text is to obtain sharp a priori estimates and decay rates for general classes of solutions in terms of estimates of particular problems These estimates are the building blocks in understanding the qualitative theory and the decay rates pave the way to the fine study of asymptotics Many technically relevant questions are presented and analyzed in detail A systematic picture of the most relevant phenomena is obtained for the equations under study including time decay smoothing extinction in finite time and delayed regularity

*Nonlinear Diffusion* William Edward Fitzgibbon, Homer Franklin Walker, 1977

*Degenerate Nonlinear Diffusion Equations* Angelo Favini, Gabriela Marinoschi, 2012-05-08 The aim of these notes is to include in a uniform presentation style several topics related to the theory of degenerate nonlinear diffusion equations treated in the mathematical framework of evolution equations with multivalued  $m$  accretive operators in Hilbert spaces The problems concern nonlinear parabolic equations involving two cases of degeneracy More precisely one case is due to the vanishing of the time derivative coefficient and the other is provided by the vanishing of the diffusion coefficient on subsets of positive measure of the domain From the mathematical point of view the results presented in these notes can be considered as general results in the theory of degenerate nonlinear diffusion equations However this work does not seek to present an exhaustive study of degenerate diffusion equations but rather to emphasize some rigorous and efficient techniques for approaching various problems involving degenerate nonlinear diffusion equations such as well posedness periodic solutions asymptotic behaviour discretization schemes coefficient identification and to introduce relevant solving methods for each of them

*Nonlinear Diffusion Equations and Their Equilibrium States I* W.-M. Ni, L.A. Peletier, James Serrin, 2012-12-06 In recent years considerable interest has been focused on nonlinear diffusion problems the archetypical equation for these being  $U_t = D u \cdot u$  Here  $D$  denotes the  $n$  dimensional Laplacian the solution  $u = u(x, t)$  is defined over some space time domain of the form  $n \times [0, T]$

and  $f(u)$  is a given real function whose form is determined by various physical and mathematical applications. These applications have become more varied and widespread as problem after problem has been shown to lead to an equation of this type or to its time independent counterpart the elliptic equation of equilibrium  $D u = f(u)$ . Particular cases arise for example in population genetics the physics of nuclear stability phase transitions between liquids and gases flows in porous media the Lend Emden equation of astrophysics various simplified combustion models and in determining metrics which realize given scalar or Gaussian curvatures. In the latter direction for example the problem of finding conformal metrics with prescribed curvature leads to a ground state problem involving critical exponents. Thus not only analysts but geometers as well can find common ground in the present work. The corresponding mathematical problem is to determine how the structure of the nonlinear function  $f(u)$  influences the behavior of the solution.

**Nonlinear Diffusion Equations and Their Equilibrium States** I.W.-M. Ni, L.A. Peletier, James Serrin, 1988-06-24. In recent years considerable interest has been focused on nonlinear diffusion problems the archetypical equation for these being  $U_t = D u + f(u)$ . Here  $D$  denotes the  $n$  dimensional Laplacian the solution  $u(x,t)$  is defined over some space time domain of the form  $n \times [0, T]$  and  $f(u)$  is a given real function whose form is determined by various physical and mathematical applications. These applications have become more varied and widespread as problem after problem has been shown to lead to an equation of this type or to its time independent counterpart the elliptic equation of equilibrium  $D u = f(u)$ . Particular cases arise for example in population genetics the physics of nuclear stability phase transitions between liquids and gases flows in porous media the Lend Emden equation of astrophysics various simplified combustion models and in determining metrics which realize given scalar or Gaussian curvatures. In the latter direction for example the problem of finding conformal metrics with prescribed curvature leads to a ground state problem involving critical exponents. Thus not only analysts but geometers as well can find common ground in the present work. The corresponding mathematical problem is to determine how the structure of the nonlinear function  $f(u)$  influences the behavior of the solution.

Nonlinear Diffusion Equations and Their Equilibrium States, 3 N.G Lloyd, M.G. Ni, L.A. Peletier, J. Serrin, 2012-01-24. Nonlinear diffusion equations have held a prominent place in the theory of partial differential equations both for the challenging and deep mathematical questions posed by such equations and the important role they play in many areas of science and technology. Examples of current interest are biological and chemical pattern formation semiconductor design environmental problems such as solute transport in groundwater flow phase transitions and combustion theory. Central to the theory is the equation  $U_t = \Delta u + f(u)$ . Here  $\Delta$  denotes the  $n$  dimensional Laplacian  $\Delta u$  and  $f$  are given functions and the solution is defined on some domain  $n \times [0, T]$  in space time. Fundamental questions concern the existence uniqueness and regularity of solutions the existence of interfaces or free boundaries the question as to whether or not the solution can be continued for all time the asymptotic behavior both in time and space and the development of singularities for instance when the solution ceases to exist after finite time either through extinction or through blow up.

The Nonlinear Diffusion Equation J.M. Burgers, 2013-12-11 Since the Introduction to the main text gives an account of the way in which the problems treated in the following pages originated this Preface may be limited to an acknowledgement of the support the work has received It started during the period when I was professor of aero and hydrodynamics at the Technical University in Delft Netherlands and many discussions with colleagues have influenced its development Of their names I mention here only that of H A Kramers Papers No 1-13 of the list given at the end of the text were written during that period Several of these were attempts to explore ideas which later had to be abandoned but gradually a line of thought emerged which promised more definite results This line began to come to the foreground in paper No 3 1939 while a preliminary formulation of the results was given in paper No 12 1954 At that time however there still was missing a practical method for manipulating a certain distribution function of central interest A six months stay at the Hydrodynamics Laboratories of the California Institute of Technology Pasadena California 1950-1951 was supported by a Contract with the Department of the Air Force No AF 33 038 17207 A course of lectures was given during this period which were published in typescript under the title On Turbulent Fluid Motion as Report No E 34 1 July 1951 of the Hydrodynamics Laboratory

*Nonlinear Diffusion Equations and Their Equilibrium States II* W.-M. Ni, L.A. Peletier, James Serrin, 2012-12-06 In recent years considerable interest has been focused on nonlinear diffusion problems the archetypical equation for these being  $U_t = U \Delta u$  Here  $\Delta$  denotes the  $n$ -dimensional Laplacian the solution  $u(x, t)$  is defined over some space-time domain of the form  $n \times [0, T]$  and  $f(u)$  is a given real function whose form is determined by various physical and mathematical applications These applications have become more varied and widespread as problem after problem has been shown to lead to an equation of this type or to its time-independent counterpart the elliptic equation of equilibrium  $U f(u) = 0$  Particular cases arise for example in population genetics the physics of nuclear stability phase transitions between liquids and gases flows in porous media the Lend-Emden equation of astrophysics various simplified combustion models and in determining metrics which realize given scalar or Gaussian curvatures In the latter direction for example the problem of finding conformal metrics with prescribed curvature leads to a ground state problem involving critical exponents Thus not only analysts but geometers as well can find common ground in the present work The corresponding mathematical problem is to determine how the structure of the nonlinear function  $f(u)$  influences the behavior of the solution

**Nonlinear Diffusion Equations and Their Equilibrium States, 3** N. G. Lloyd, 1992-01-01 *Travelling Waves in Nonlinear Diffusion-Convection Reaction* Brian H. Gilding, Robert Kersner, 2004-07-23 This monograph has grown out of research we started in 1987 although the foundations were laid in the 1970s when both of us were working on our doctoral theses trying to generalize the now classic paper of Oleinik-Kalashnikov and Chzhou on nonlinear degenerate diffusion Brian worked under the guidance of Bert Peletier at the University of Sussex in Brighton England and later at Delft University of Technology in the Netherlands on extending the earlier mathematics to include nonlinear convection while Robert worked at Lomonosov State University in Moscow under the supervision of

Anatolii Kalashnikov on generalizing the earlier mathematics to include nonlinear absorption We first met at a conference held in Rome in 1985 In 1987 we met again in Madrid at the invitation of Ildefonso Diaz where we were both staying at La Residencia As providence would have it the University Complutense closed down during this visit in response to student demonstrations and we were very much left to our own devices It was natural that we should gravitate to a research topic of common interest This turned out to be the characterization of the phenomenon of finite speed of propagation for nonlinear reaction convection diffusion equations Brian had just completed some work on this topic for nonlinear diffusion convection while Robert had earlier done the same for nonlinear diffusion absorption There was no question but that we bundle our efforts on the general situation

### **Solutions of a Family of Nonlinear Diffusion Equations for Semi-infinite Media**

Ray E. Kidder,1962 **Nonlinear Diffusion Equations and Curvature Conditions in Metric Measure Spaces** Luigi Ambrosio,Andrea Mondino,Giuseppe Savaré,2019 Aim of this paper is to provide new characterizations of the curvature dimension condition in the context of metric measure spaces  $X, d, m$  On the geometric side our new approach takes into account suitable weighted action functionals which provide the natural modulus of  $K$  convexity when one investigates the convexity properties of  $N$  dimensional entropies On the side of diffusion semigroups and evolution variational inequalities our new approach uses the nonlinear diffusion semigroup induced by the  $N$  dimensional entropy in place of the heat flow Under suitable assumptions most notably the quadraticity of Cheeger's energy relative to the metric measure structure both approaches are shown to be equivalent to the strong CD  $K, N$  condition of Bacher Sturm Dual Variational Approach to Nonlinear Diffusion Equations Gabriela Marinoschi,2023-03-28 This monograph explores a dual variational formulation of solutions to nonlinear diffusion equations with general nonlinearities as null minimizers of appropriate energy functionals The author demonstrates how this method can be utilized as a convenient tool for proving the existence of these solutions when others may fail such as in cases of evolution equations with nonautonomous operators with low regular data or with singular diffusion coefficients By reducing it to a minimization problem the original problem is transformed into an optimal control problem with a linear state equation This procedure simplifies the proof of the existence of minimizers and in particular the determination of the first order conditions of optimality The dual variational formulation is illustrated in the text with specific diffusion equations that have general nonlinearities provided by potentials having various stronger or weaker properties These equations can represent mathematical models to various real world physical processes Inverse problems and optimal control problems are also considered as this technique is useful in their treatment as well Analysis of Nonlinear Diffusion Equations of Second and Fourth Order Maria Pia Gualdani,2005 **Nonlinear Diffusion Equations and Their Equilibrium States II** W.-M. Ni,L.A. Peletier,James Serrin,1988-06-24 In recent years considerable interest has been focused on nonlinear diffusion problems the archetypical equation for these being  $U_t - U \Delta u = f(u)$  Here denotes the  $n$  dimensional Laplacian the solution  $u = u(x, t)$  is defined over some space time domain of the form  $[0, \infty) \times \Omega$  and  $f(u)$  is a given real

function whose form is determined by various physical and mathematical applications. These applications have become more varied and widespread as problem after problem has been shown to lead to an equation of this type or to its time independent counterpart the elliptic equation of equilibrium  $u = f(u)$ . Particular cases arise for example in population genetics, the physics of nuclear stability, phase transitions between liquids and gases, flows in porous media, the Lane-Emden equation of astrophysics, various simplified combustion models and in determining metrics which realize given scalar or Gaussian curvatures. In the latter direction for example the problem of finding conformal metrics with prescribed curvature leads to a ground state problem involving critical exponents. Thus not only analysts but geometers as well can find common ground in the present work. The corresponding mathematical problem is to determine how the structure of the nonlinear function  $f(u)$  influences the behavior of the solution.

Reduced Basis for Nonlinear Diffusion Equations Mohammad Rasty, 2016      **On the Solution of Nonlinear Diffusion Equations** M. J. Baines, 1988



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