

# **TRENDS IN THEORY AND PRACTICE OF NONLINEAR DIFFERENTIAL EQUATIONS**

edited by

**V. LAKSHMIKANTHAM**

# **TRENDS IN THEORY AND PRACTICE OF NONLINEAR DIFFERENTIAL EQUATIONS**

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**V. LAKSHMIKANTHAM**

*Department of Mathematics  
University of Texas at Arlington  
Arlington, Texas*

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## DEDICATION

Dear Fellow Mathematicians:

I have the great privilege to introduce to you Professor E. A. Coddington, a prominent figure of the international mathematical community, and a leading contributor to the theory of ordinary differential operators and equations.

I gladly take the opportunity to present some of the highlights of the outstanding career of Professor Coddington. This presentation is not easy, due to an outstanding record of academic achievements, and due to a very fine personality Professor Coddington embodies. Nevertheless, I will try my best, and at the same time try to comply with what is becoming now a tradition of the mathematical conferences held at The University of Texas at Arlington - to extol the activity of one of our colleagues who has brought an exceptional contribution, a long standing contribution, to the promotion of research in the field of Differential Equations.

Professor Coddington started his mathematical career in 1942--exactly 41 years ago. Until 1946, he was associated with the Navy Department. In 1946 Professor Coddington returned to school for graduate studies and for two consecutive years he was associated with the Johns Hopkins University where he obtained his Ph.D. in 1948. The academic year 1948-1949 for Professor Coddington was spent at Johns Hopkins University where he held an instructorship in mathematics. The next three years, from 1949 to 1952, were spent at the Massachusetts Institute of Technology - again, as an instructor in mathematics.

Since 1952, Professor Coddington was associated with The University of California at Los Angeles where he successively held the positions of Assistant, Associate, and full Professor (the latter, since 1959). From 1968 until 1971, Professor Coddington served as Chairman of the Mathematics Department at The University of California at Los Angeles.

During the period 1955-1981, Professor Coddington held visiting posi-



Professor E. A. Coddington

tions at various universities including: Princeton University (1957-1958), University of Copenhagen (1955-1956 and 1963-1964; as a Fulbright Scholar), University of Paris VI (1972), University of London, Chelsea College (1981) and the Universities of Beijing and Canton (1981).

Besides an impressive number of research papers published in various American and foreign mathematical journals, most of which are dedicated to the theory of differential operators, Professor Coddington has authored a famous treatise *Theory of Ordinary Differential Equations* - jointly with the late MIT professor Norman Levinson (first published by McGraw-Hill

Publishing Co. in 1955), a textbook entitled *An Introduction to Ordinary Differential Equations* (first published by Prentice-Hall in 1958), and recently he has coauthored (with Henrik S. V. de Snoo) the monograph *Regular Boundary Value Problems Associated with Pairs of Ordinary Differential Expressions* - a Springer-Verlag publication in the Lecture Notes in Mathematics Series (1981).

In regard to the treatise *Theory of Ordinary Differential Equations*, one can assert without any doubt that it became the basic reference book in this field for several generations of mathematicians all around the world. Indeed, in 1958, a Russian edition has been published in Moscow. The book has enjoyed a wide circulation not only in the Soviet Union, but also in most East European Countries. A Japanese translation - in two volumes - came out at Yoshioka Publishing House in 1969. In 1972 a reprint of the book came out in India, and according to the testimony of our colleagues in that country, it has been a very successful project. If one thinks that the original English edition has been circulating in the Western World, one can conclude that the *Theory of Ordinary Differential Equations* authored by Coddington and Levinson has indeed enjoyed a world-wide circulation as one of the most authoritative sources in the field. I had the opportunity to use the book in teaching graduate courses in Differential Equations during the period 1958-1962 and I remember the delight of my students in connection with the treatment of most of the classical or less classical problems discussed in the book. The chapter concerning the differential systems in the plane contains so many innovations and is presented in such an attractive manner, that hardly anyone could challenge the presentation of this topic. If nowadays it is very fashionable to deal with integral manifolds, it seems that the first approach to this matter is the one in the book by Coddington and Levinson. There are many more outstanding features of this book and there is no wonder that it still constitutes a basic reference item for researchers in the theory of differential equations. R. Bellman has written a very enthusiastic review of the book in the Bulletin of the AMS, and after almost three decades have passed since its publication, we can ascertain the fact that this is a landmark in the history of differential equations.

The second book Professor Coddington has published constitutes an excellent introductory textbook to the field of Ordinary Differential Equations. In addition to the English version, several foreign publishing houses have produced their versions: Maruzen Co. Ltd. published the

Japanese version in Tokyo in 1964, Prentice-Hall of India reprinted the book in New Delhi in 1968; finally, a Spanish edition was produced by Compañía Editorial Unilimited in Mexico City in 1968.

The third book, authored by Professor Coddington and Henrik S. V. de Snoo, is a monograph dealing with some of the most recent investigations undertaken by the authors. It certainly develops and pursues ideas that appeared in the previous work of the first author, as well as some ideas originated by such famous mathematicians as E. Kamke, E. Hölder, M. G. Krein, and M. A. Naimark. I am not going to present in detail this monograph since Professor Coddington's invited address will be dedicated to the spectral theory of pairs of ordinary differential operators - a topic which seems to be closely related to the ideas developed in the monograph.

Most of Professor Coddington's research work was oriented toward the solution of boundary value problems for systems of ordinary differential equations, involving such core aspects as eigenfunctions expansion, the definition of the adjoint operator, extension of differential operators, and many others.

Identifying the operators with their graphs in the product space, most properties can be formulated in terms of linear manifolds or subspaces of the product space. A theory of linear relations has been built up and successfully developed by Professor Coddington and his co-workers with salient applications to the classical boundary value problems for ordinary differential systems. It is proven that multipoint boundary conditions, and more generally, boundary conditions involving Stieltjes integral, can be dealt with as special cases of the general results obtained in the abstract framework.

In concluding this concise presentation of Professor Coddington's outstanding contribution to the theory of differential equations, I would like to express - and I am sure I can do it on behalf of all the participants - our warmest congratulations to him, and our hope that this conference will emphasize much more than I was able to point out in this brief introductory speech.

Professor C. Corduneanu

## PREFACE

An International Conference on *Trends in Theory and Practice of Nonlinear Differential Equations* was held at The University of Texas at Arlington during June 14-18, 1982. This conference was sponsored by the U. S. Army Research Office and The University of Texas at Arlington. This was the fifth in a series of conferences organized by The University of Texas at Arlington. It is a pleasure to acknowledge the financial support received from the various sponsoring agencies which made the conference possible.

The present volume consists of the proceedings of the conference. It includes papers that were delivered as invited survey talks and research reports as well as contributed papers. There were well over eighty talks and sixteen countries were represented.

The aim of the conference was to feature recent trends in theory and practice of nonlinear differential equations. The following topics were discussed: spectral theory for symmetric pairs of differential operators, Lotka-Volterra systems, generalized inverses for linear manifolds, nonlinear problems at resonance, steepest descent methods, reaction-diffusion equations, Lyapunov stability, stochastic differential equations, comparison and frequency domain techniques, delay differential equations, method of upper and lower solutions, Newton-like methods, periodic solutions of nonlinear problems, population biology, effects of harvesting on population systems, models of toxicant population, nonlinear equations of heat flow, inclusion principle for hereditary systems, neuromuscular systems, transform techniques in qualitative theory of systems, vector Lyapunov functions in the analysis of dynamical properties of differential equations, recent topics on nonlinear contraction semi-groups, set valued extensions of integral inequalities, global controllability of nonlinear delay systems, cone-valued Lyapunov functions, large-scale systems, quasi-solutions, almost periodicity of solutions of parabolic equations, generalized Hopf bifurcation and exchange of stability and nonlinear elliptic problems.

At the conference the participants honored Professor Earl A. Coddington of The University of California at Los Angeles for his valuable contributions to differential equations.

I wish to express my special thanks to my colleagues Professors C. Corduneanu, S. Bernfeld, J. Bolen and G. Ladde for helping me in planning and organizing the conference and to my secretaries Mrs. Gloria Brown, Mrs. Cindy Murdock, Mr. Marian Pruiett, and Mrs. Karen Stafford for assisting me during the conference. I am extremely thankful to Mrs. Pruiett and Mrs. Stafford for their excellent typing and finalizing the proceedings of the conference. My immense thanks are due to publishers Marcel Dekker, Inc. for their cooperation.

V. Lakshmikantham

# CONTRIBUTORS

- Abdelaziz, Nazar Hussein - Kuwait University, Kuwait.
- Aftabizadeh, A. R. - Pan American University, Edinburg, Texas.
- Ahmad, Shair - University of Miami, Coral Gables, Florida.
- Asner, Bernard A. - University of Dallas, Irving Texas.
- Akinyele, Olusola - Iowa State University, Ames, Iowa\*\*
- Amirat, Y. - Institut de Mathématiques, U.S.T.H.B., Dar El Beida, Algeria.
- Bajaj, Prem N. - Wichita State University, Wichita, Kansas.
- Baxley, John V. - Wake Forest University, Winston-Salem, North Carolina.
- Becker, Ronald I.\* - University of Cape Town, Rondebosch, South Africa.
- Benharbit, Abdelali - Pennsylvania State University, York, Pennsylvania.
- Bernfeld, S. R. - University of Texas at Arlington, Arlington, Texas.
- Block, Louis - University of Florida, Gainesville, Florida.
- Brauer, Fred - University of Wisconsin, Madison, Wisconsin.
- Burbea, Jacob - University of Pittsburgh, Pittsburgh, Pennsylvania.
- Burton, T. A. - Southern Illinois University, Carbondale, Illinois.
- Ghan, C. Y. - Florida State University, Tallahassee, Florida.
- Chandra, Jagdish - U. S. Army Research Office, Research Triangle Park, North Carolina.
- Chukwu, E. N. - Federal University of Technology, Yola, Nigeria.
- Coddington, Earl A. - University of California, Los Angeles, California.
- Corduneanu, C. - University of Texas at Arlington, Arlington, Texas.
- Dahiya, R. S. - Iowa State University, Ames, Iowa.
- Dannan, Fozi M. - Kuwait University, Kuwait.
- Diaz, Ildefonso - University of Santander, Santander, Spain.
- Driver, R. D. - University of Rhode Island, Kingston, Rhode Island.
- Eisenfeld, J. - University of Texas at Arlington, Arlington, Texas.
- Elaydi, Saber - Kuwait University, Kuwait.

\*Present address: University of Tennessee, Knoxville, Tennessee.

\*\*Present address: Department of Mathematics, University of Ibadan, Nigeria.

- El kolli, Amar - O.N.R.S. - Institut de Mathématiques, U.S.T.H.B., Dar El Beida, Algeria.
- Fitzgibbon, W. E. - University of Houston, Houston, Texas.
- Goldstein, Jerome A. - Tulane University, New Orleans, Louisiana.
- Gosse, J. P. - Université Libre de Bruxelles, Bruxelles, Belgium.
- Gregory, John - Southern Illinois University, Carbondale, Illinois.
- Grisell, R. D. S. - Texas Instruments, Dallas, Texas.
- Gupta, Chaitan P. - Northern Illinois University, DeKalb, Illinois.
- Ha, Ki Sik - Busan National University, Busan, Korea.
- Haberman, Richard - Southern Methodist University, Dallas, Texas.
- Hadeler, K. P. - Lehrstuhl für Biomathematik, Universität Tübingen, Tübingen, West Germany
- Hallam, Thomas G. - Department of Mathematics and Program in Ecology, University of Tennessee, Knoxville, Tennessee.
- Hart, David - University of Florida, Gainesville, Florida.
- Hatvani, L. - Bolyai Institute, Aradi vértanúk t. 1, Szeged, Hungary.
- Hernández, Jesus - Departamento de Matemáticas, Universidad Autónoma, Madrid, Spain
- Hulbert, Douglas S. - University of Southern California, Los Angeles, California.
- Kaul, S. K. - University of Regina, Regina, Saskatchewan, Canada.
- Knight, Ronald A. - Northeast Missouri State University, Kirksville, Missouri.
- Ko, Fung-Tai - University of Texas at Arlington, Arlington, Texas.
- Ladas, G. - University of Rhode Island, Kingston, Rhode Island.
- Ladde, G. S. - University of Texas at Arlington, Arlington, Texas.
- Lakshmikantham, V. - University of Texas at Arlington, Arlington, Texas.
- Lazer, A. C. - University of Miami, Coral Gables, Florida.
- Lee, Sung J. - University of South Florida, Tampa, Florida.
- Leela, S. - Department of Mathematics, State University of New York, (SUNY), Genesee, New York.
- Londen, S.-O. - Department of Mathematics, Helsinki University of Technology, Espoo 15, Finland.
- Louis, J.-Cl. - Facultés Universitaires Notre-Dame de la Paix, Belgium.
- McKenna, P. J. - Department of Mathematics, University of Florida, Gainesville, Florida.
- Mahfoud, W. E. - Murray State University, Murray, Kentucky.
- Makhlof, Rafiq - University of Southern California, Los Angeles, California.
- Matrosov, V. M. - Computer Centre, Irkutsk, U.S.S.R.
- Miyadera, Isao - Waseda University, Shinjuku-ku, Tokyo, Japan

- Montes de Oca, Francisco<sup>\*</sup> - Department of Mathematics, University of Miami, Coral Gables, Florida.
- Moore, R. E. - Department of Mathematics, University of Texas at Arlington, Arlington, Texas.
- Nagle, R. Kent - Department of Mathematics, University of South Florida, Tampa, Florida.
- Nashed, Z. - Department of Mathematics, University of Delaware, Newark, Delaware.
- Neuberger, John W. - Department of Mathematics, North Texas State University, Denton, Texas.
- Nieto, J. J. - Facultad de Matematicas, Universidad de Santiago, Spain.
- Nohel, J. A. - University of Wisconsin, Madison, Wisconsin.
- Oğuztöreli, M. Namik - Department of Mathematics, University of Alberta, Edmonton, Alberta, Canada
- Ohta, Y. - Fukui University, Fukui-shi, Japan.
- Olas, Andrzej<sup>†</sup> - Institute of Fundamental Technological Research, Warsaw, Poland.
- Pandian, M. C. - University of Texas at Arlington, Arlington, Texas.
- Pao, C. V. - Department of Mathematics, North Carolina State University, Raleigh, North Carolina.
- Payne, Fred R. - Department of Aerospace Engineering, University of Texas at Arlington, Arlington, Texas.
- Perry, W. L. - Texas A&M University, College Station, Texas.
- Popov, V. M. - University of Florida, Gainesville, Florida.
- Redheffer, Ray - University of California, Los Angeles, California.
- Reich, Simeon - University of Southern California, University Park, Los Angeles, California.
- Sandefur, James T. - Georgetown University, Washington, D.C., and Cornell University, Ithaca, New York.
- Sficas, Y. G. - University of Rhode Island, Kingston, Rhode Island.
- Shendge, G. R. - University of Iowa, Iowa City, Iowa.
- Shivaji, Ratnasingham - Yarmouk University, Jordan.
- Šiljak, D. D. - University of Santa Clara, Santa Clara, California.
- Smith, Hal L. - Arizona State University, Tempe, Arizona.
- Stavroulakis, I. P. - University of Rhode Island, Kingston, Rhode Island.
- Umamaheswaram, S. - University of Hyderabad, Hyderabad, India.
- Vaisman, I. - University of Haifa, Haifa, Israel.
- Vargas, C. - University of Texas at Arlington, Arlington, Texas.
- Vatsala, A. S. - Bishop College, Dallas, Texas.

---

<sup>\*</sup>Permanent address: Universitario Politécnico, Barquisimeto, Venezuela.

<sup>†</sup>Temporary address: Tuskegee Institute, Alabama.

- Vorel, Zdenek - University of Southern California, Los Angeles, California.  
Wexler, D. - Facultes Universitaires de Namur, Belgium.  
Wiener, Joseph - Pan American University, Edinburg, Texas.  
Yoshizawa, Taro - Tohoku University, Sendai, Japan  
Zeman, Marvin - Southern Illinois University, Carbondale, Illinois.  
Ziani, A. - Institut de Mathématiques, U.S.T.H.B., Dar El Beida, Algeria.

## OTHER PARTICIPANTS

- Dragan, I. - University of Texas at Arlington, Arlington, Texas.  
Lui, Roger - San Diego State University, San Diego, California.  
Moebes, Travis A. - Houston, Texas.  
Pandit, Sudhakar G. - Christopher Newport College, Newport News, Virginia.  
Parrott, Mary E. - University of South Florida, Tampa, Florida.  
Rio, Sheldon T. - School of Science/Mathematics, Ashland, Oregon.  
Sambandham, M.- Georgia Institute of Technology, Atlanta, Georgia.  
Sarhan, Mahmoud - University of Petroleum and Minerals, Dhahran, Saudi Arabia.  
Schröder, Johann - Mathematisches Institut, Universität Köln, Köln, West Germany.  
Torres, Euclides E. - Dallas, Texas.  
Tsay, Y. T. - Department of Electrical Engineering, University of Houston, Houston, Texas.  
Vidyasagar, M. - University of Waterloo, Waterloo, Ontario, Canada.  
Waak, Tom - Bell Helicopter, Fort Worth, Texas.