

Martin Feinberg

- Present Position:*** Richard M. Morrow Professor Emeritus of Chemical & Biomolecular Engineering and Professor Emeritus of Mathematics
The Ohio State University
Koffolt Laboratories
151 West Woodruff Avenue
Columbus, Ohio 43210
Phone (614) 688 4883 Fax (614) 292 3769
E-Mail: FEINBERG.14@OSU.EDU
- Previous Position:*** Professor of Chemical Engineering, University of Rochester
(University of Rochester employment from 1967-1997)
- Visiting Positions:*** Physical Chemistry Laboratory, Oxford University, fall, 1974
Mathematics Research Center, University of Wisconsin, fall, 1979
Institute for Mathematics and its Applications, University of Minnesota, summer, 1983
Visiting Professor, Department of Chemical Engineering, University of the Witwatersrand, Johannesburg, South Africa, September, 1992
Visiting Professor, Department of Systems Biology, Harvard Medical School, February-August, 2007.
- Education:*** (All in chemical engineering)

B.Ch.E., Cooper Union (1962)
M.S., Purdue University (1963)
Ph.D., Princeton University (1968)
- Honors:*** Camille & Henry Dreyfus Teacher-Scholar, 1973
Edward Peck Curtis Award for Excellence in Undergraduate Teaching, 1994 (Awarded at Commencement to just one University of Rochester faculty member each year.)
Plenary Lecturer, Third SIAM Conference on Applications of Dynamical Systems, 1995
Richard Wilhelm Award of the American Institute of Chemical Engineers, 1996
John von Neumann Memorial Lecture in Theoretical Biology, Institute for Advanced Study, Princeton, N.J., 1997
MacQuigg Award for Undergraduate Teaching, Ohio State, 1999
Scott Faculty Award for Research and Teaching, Ohio State, 2001
Distinguished Scholar Award, Ohio State University, 2005
Amundson Lectures, University of Houston, December, 2005
Wilhelm Lectures, Princeton University, October, 2011
Ohio State University Alumni Distinguished Teaching Award, 2014
William Pierson Field Lectures, Princeton University, 2018

Publications

Sufficient conditions for the stability of fluid motions constitutively described by the infinitesimal theory of viscoelasticity, *Industrial and Engineering Chemistry Fundamentals*, **8**, 332, (1969) (with W. Schowalter).

Conditions for the stability of cylindrical Couette flow of certain viscoelastic liquids, *Proceeding of the Fifth International Congress on Rheology*, Vol. 1, (ed. S. Onogi) University Park Press (1969) (with W. Schowalter).

On chemical kinetics of a certain class, *Archive for Rational Mechanics and Analysis*, **46**, 1-41, (1972).

Complex balancing in general kinetic systems, *Archive for Rational Mechanics and Analysis*, **49**, 187-194, (1972).

Dynamics of open chemical systems and the algebraic structure of the underlying reaction network, *Chemical Engineering Science*, **29**, 775-787, (1974) (with F. J. M. Horn).

Remarks on a paper by B. F. Gray and L. J. Aarons, *Symposia of the Faraday Society*, (Physical Chemistry of Oscillatory Phenomena), (1975).

Review of G. Astarita's *Introduction to Nonlinear Continuum Thermodynamics*, *Chemical Engineering Education*, summer issue (1976).

Constitutive equations for ideal gas mixtures and ideal solutions as consequences of simple postulates, *Chemical Engineering Science*, **32**, 75-78, (1977).

Chemical mechanism structure and the coincidence of the stoichiometric and kinetic subspaces, *Archive for Rational Mechanics and Analysis*, **66**, 83-97, (1977) (with F. J. M. Horn).

Mathematical Aspects of Mass Action Kinetics, Chapter 1 (pp. 1 - 78) in *Chemical Reactor Theory: A Review* (eds. N. Amundson and L. Lapidus), Prentice-Hall, Englewood Cliffs, N.J. (1977).

On Gibbs's phase rule, *Archive for Rational Mechanics and Analysis*, **70**, 219-234, (1979).

Chemical Oscillations, Multiple Equilibria, and Reaction Network Structure, pp. 59-130 in *Dynamics and Modelling of Reactive Systems* (eds. Warren Stewart, W. Harmon Ray, and Charles Conley), Academic Press, New York (1980).

On a generalization of linear independence in finite-dimensional vector spaces, *Journal of Combinatorial Theory, Series B*, **30**, 61-69, (1981).

Reaction Network Structure, Multiple Steady States and Sustained Composition Oscillations: A Review of Some Results, pp. 56-68 in *Modelling of Chemical Reaction Systems* (eds. K.H. Ebert, P. Deuflhard, W. Jäger) Springer-Verlag, Berlin-Heidelberg-New York, (1981).

Thermodynamics based on the Hahn-Banach theorem: the Clausius inequality, *Archive for Rational Mechanics and Analysis*, **82**, 203-293, (1983) (with Richard B. Lavine).

Foundations of the Clausius-Duhem Inequality, pp. 123-140 in C. Truesdell's *Rational Thermodynamics, Second Edition*, Springer-Verlag, Berlin-Heidelberg-New York (1984) (with Richard B. Lavine).

A new test for the possibility of multiple steady states in isothermal reactors with complex chemistry, *Proceedings of the First Annual Link Conference on Energy*, (1985) (with Paul Schlosser).

Thermodynamics and the Hahn-Banach Theorem, pp. 115-118 in *Categories in Continuum Physics*, ed. W. Lawvere, Springer-Verlag, Berlin-Heidelberg- New York (1986) (with Richard B. Lavine).

Foundations of the Clausius-Duhem Inequality, pp. 49-64 in *New Perspectives in Thermodynamics* (editor James Serrin), Springer-Verlag, Berlin- Heidelberg-New York (1986) (with Richard B. Lavine).

A Graphical Determination of the Possibility of Multiple Steady States in Complex Isothermal CFSTRs in *Complex Chemical Reaction Systems: Mathematical Modelling and Simulation*, 102 - 114, eds. W. Jäger and J. Warnatz, Springer-Verlag, Berlin-Heidelberg-New York, 1987 (with Paul Schlosser).

Chemical reaction network structure and the stability of complex isothermal reactors: I. The deficiency zero and deficiency one theorems, *Chemical Engineering Science*, **42**, 2229-2268, 1987.

Chemical reaction network structure and the stability of complex isothermal reactors: II. Multiple steady states for networks of deficiency one, *Chemical Engineering Science*, **43**, 1-25, 1988.

Multiple steady states in complex isothermal CFSTRs: I. General considerations, *Chemical Engineering Science*, **43**, 321-328, 1988 (with T.M. Lieb and D. Rumschitzki).

Multiple steady states in complex isothermal CFSTRs: II. Homogeneous reactors, *Chemical Engineering Science*, **43**, 329-337, 1988 (with D. Rumschitzki).

Necessary and sufficient conditions for detailed balancing in mass action systems of arbitrary complexity, *Chemical Engineering Science*, **44**, 1819-1827, 1989 (invited paper in honor of Rutherford Aris).

Applications of Chemical Reaction Network Theory in Heterogeneous Catalysis, pp. 178-196 *Chemical Reactions in Complex Systems: The Mobil Workshop*, eds. A.V. Sapre and F. J. Krambeck, D. Van Nostrand, New York, 1991.

Some Recent Results in Chemical Reaction Network Theory, pp. 43-70 in *Patterns and Dynamics in Reactive Media*, eds R. Aris, D. Aronson and H. Swinney, Springer-Verlag, Berlin-Heidelberg-New York, 1991.

Traveling composition waves on isothermal catalyst surfaces, *Archive for Rational Mechanics and Analysis*, **116**, 35-69, 1991 (with David Terman).

Multiple steady states as a source of pattern formation in complex multicell systems, *Chemical Engineering Science*, **48**, 4143-4151, 1993 (with Marcelo Korc).

A theory of multiple steady states in isothermal homogeneous CFSTRs with many reactions, *Chemical Engineering Science*, **49**, 1749-1767, 1994 (with Paul M. Schlosser).

The existence and uniqueness of steady states for a class of chemical reaction networks, *Archive for Rational Mechanics and Analysis*, **132**, 311-370, 1995.

Multiple steady states for chemical reaction networks of deficiency one, *Archive for Rational Mechanics and Analysis*, **132**, 371-406, 1995.

Optimal reactor design from a geometric viewpoint: I. Universal properties of the attainable region, *Chemical Engineering Science*, **52**, 1637-1665, 1997, (with Diane Hildebrandt).

Recent results in optimal reactor synthesis via attainable region theory, *Chemical Engineering Science*, **54**, 2535-2543, 1999.

Optimal reactor design from a geometric viewpoint: II. Critical sidestream reactors, *Chemical Engineering Science* **55**, 2455-2479, (2000).

Optimal reactor design from a geometric viewpoint: III. Critical CFSTRs, *Chemical Engineering Science*, **55**, 3553-3565, (2000).

How catalytic mechanisms reveal themselves in multiple steady state data. I. Basic principles, *The Journal of Molecular Catalysis A: Chemical*, **154**, 155 – 167, (2000) (with Phillipp Ellison)

How catalytic mechanisms reveal themselves in multiple steady state data. II. An ethylene hydrogenation example, *The Journal of Molecular Catalysis A: Chemical*, **154**, 169 – 184, 2000 (with Phillipp Ellison, M.-H. Yue and H. Saltsburg)

General kinetic bounds on productivity and selectivity in reactor-separator systems of arbitrary design: Principles, *Ind. Eng. Chem. Res.*, **40**, 3181-3194 (2001). (with Phillipp Ellison).

Toward a theory of process synthesis, *Ind. Eng. Chem. Research*, **41**, 3751-3761, (2002).

Geometric control theory and classical problems of chemical reactor design, Proceedings of 15th IFAC World Congress, Barcelona, 441-446, Elsevier (2003).

Kinetic bounds on attainability in the reactor synthesis problem, *Ind. Eng. Chem. Res.*, **43**, 449-457 (2004). (with Thomas K. Abraham).

Multiple equilibria in complex chemical reaction networks: I. The injectivity property, *S.I.A.M. Journal of Applied Mathematics*, **65**, 1526-1546, 2005 (with Gheorghe Craciun).

Multiple equilibria in complex chemical reaction networks: II. The species-reaction graph, *S.I.A.M. Journal of Applied Mathematics*, **66**, 1321-1338, 2006 (with Gheorghe Craciun).

Multiple equilibria in complex chemical reaction networks: Extensions to entrapped species models, *I.E.E. Proc. Systems Biology*, **153**, 179-186, 2006. (with Gheorghe Craciun).

Understanding bistability in complex enzyme-driven reaction networks, *Proceedings of the National Academy of Sciences USA* **103**, 8697-8702, 2006 (with Gheorghe Craciun and Yvonne Tang).

Carnot-like limits to productivity, *Ind. Eng. Chem. Res.*, **46**, 5624-5630, 2007 (with Yvonne Tang).

Sensitivity and robustness in chemical reaction networks, *S. I. A. M. Journal on Applied Mathematics*, **69**, 977-998 (2009) (with Guy Shinar and Uri Alon).

Multiple equilibria in complex chemical reaction networks: Semi-open mass action systems, *S. I. A. M. Journal on Applied Mathematics*, **70**, 1859-1877 (2010) (with Gheorghe Craciun).

Structural sources of robustness in biochemical reaction networks, *Science*, **327**, 1389 -1391, (2010) (with Guy Shinar).

Constraints on reciprocal flux sensitivities in biochemical reaction networks, *The Biophysical Journal*, **100**, 1383-1391, 2011 (with G. Shinar, A. Mayo, and H. Ji).

Design principles for robust biochemical reaction networks: What works, what cannot work, and what might almost work, *Mathematical Biosciences*, **231**, 39-49 (2011) (with G. Shinar).

Concordant chemical reaction networks, *Mathematical Biosciences*, **240**, 92-113 (2012) (with G. Shinar).

Concordant chemical reaction networks and the Species-Reaction Graph, *Mathematical Biosciences*, **241**, 1-23 (2013) (with G. Shinar)

Stability and instability in isothermal CFSTRs with complex chemistry: Some recent results, *AIChE Journal*, **59**, 3403-3411 (2013) (with G. Shinar, Haixia Ji, and Daniel Knight)

Sharper graph-theoretical conditions for the stabilization of complex chemical reaction networks, *Mathematical Biosciences*, 262, 10-27 (2015) (with D.Knight and G.Shinar)

On the steady states of weakly reversible chemical reaction networks, submitted to *S. I. A. M. Journal of Dynamical Systems*) available at <http://arxiv.org/abs/1111.2386> (with J. Deng, C. Jones, A. Nachman).

Chemical Reactions, chapter in *The Princeton Companion to Applied Mathematics*, eds. N.Higham et al., 627- 634, Princeton University Press, Princeton , NJ (2015)

Book

Foundations of Chemical Reaction Network Theory, 454 pages, Springer, (2019).

<https://www.springer.com/gp/book/9783030038571>

Software

The Chemical Reaction Network Toolbox, Versions 1.00 (1994) - 1.1 (1999), appx. 70,000 lines of code, distributed widely on the Internet with over 10,000 downloads from the University of Rochester site alone. [Version 1.1 with Phillipp Ellison] Available at <https://crnt.osu.edu/crntwin>

The Chemical Reaction Network Toolbox, Version 2.35 (2019) (with P. Ellison, H. Ji, and D. Knight), Available at <https://crnt.osu.edu/crntwin>.

Lecture Notes

Lectures on Chemical Reaction Networks, written versions of Lectures 1 - 5 (out of nine) delivered at the Mathematics Research Center, University of Wisconsin, fall, 1979. Available at <https://crnt.osu.edu/LecturesOnReactionNetworks>

Editorial

Editorial Board, *Archive for Rational Mechanics and Analysis*, 1978-1991.

Analysis and Thermomechanics: A Collection of Papers Dedicated to Walter Noll, eds. B.D. Coleman, M. Feinberg and J. Serrin, Springer-Verlag, Berlin-Heidelberg-New York, 1987.

Analysis and Continuum Mechanics: A Collection of Papers Dedicated to J. Serrin, eds. S.S. Antman, H. Brezis, B.D. Coleman, M. Feinberg, J.A. Nohel, and W.P. Ziemer, Springer-Verlag, Berlin-Heidelberg- New York, 1989.

Invited Lectures at Universities

- Department of Mechanics, The Johns Hopkins University, April, 1971
- Department of Chemical Engineering, Princeton University, October, 1971
- International Center for Mechanical Sciences, Udine, Italy, June, 1971, (5 lectures)
- Department of Chemical Engineering, Carnegie-Mellon University, April, 1972
- Department of Mathematics, Carnegie-Mellon University, April, 1972
- Department of Chemical Engineering, McMaster University, August, 1972
- Department of Chemical Engineering, SUNY-Buffalo, October, 1973
- Department of Chemical Engineering, Rice University, February, 1974
- National Science Foundation Joint Italian-American Symposium on Mixtures and Structured Continua, International Center for Mechanical Sciences, Udine, Italy, June, 1974
- Department of Physical Chemistry, Oxford University, October, 1974
- Mathematical Institute, Oxford University, November, 1974
- Department of Engineering Science, Oxford University, December, 1974
- Department of Chemical Engineering, University of Florida, March, 1975
- Applied Mathematics Seminar, Cornell University, April, 1975
- British Scientific Research Council Rencontre on Combinatorial Theory and Applications, University of Aberdeen, Aberdeen, Scotland, June, 1975.
- Department of Mathematics, University of Rochester, October, 1978
- Department of Chemistry, University of Rochester, March, 1978
- National Science Foundation Italian-American Conference on Nonlinear Continua, Venice, May, 1978
- National Science Foundation Conference on Mathematical Foundations of Thermodynamics, Ball State University, Muncie, Indiana, July, 1978
- Department of Chemical Engineering, Princeton University, April, 1979

Advanced Seminar on the Dynamics and Modelling of Reactive Systems,
University of Wisconsin, October, 1979

Department of Mathematics, University of Minnesota, November, 1979

Department of Chemical Engineering, University of Wisconsin, December,
1979

Department of Mathematics, SUNY-Buffalo, April, 1980

Department of Mathematics, University of Michigan, February, 1980

American Mathematical Society (invited lecture), Philadelphia, April, 1980

Spring Applied Mathematics Days, SUNY-Buffalo, April, 1980

Department of Chemical Engineering, University of Houston, April, 1980

Workshop on the Modelling of Chemical Reaction Systems, University of
Heidelberg, Heidelberg, W. Germany, September, 1980

Department of Chemical Engineering, Purdue University, October, 1980

Conference on Modern Developments in Continuum Thermodynamics,
University of Missouri, Rolla, November, 1980

Department of Chemical Engineering, University of Notre Dame, April, 1981

Department of Chemical Engineering, California Institute of Technology,
May, 1981

Department of Chemical Engineering, University of Pennsylvania, October,
1981

Department of Chemical Engineering, Lehigh University, October, 1981

Department of Chemical Engineering, Princeton University, October, 1981

Eastman Kodak Research Laboratories, March, 1982

Gordon Research Conference, July, 1982

Applied Mathematics Colloquium, Princeton University, April, 1983

Institute for Mathematics and its Applications, University of Minnesota, June, 1983
(2 lectures)

Department of Mathematics, University of Arizona, March, 1984

Sandia National Laboratories, March, 1984

Department of Chemical Engineering, Purdue University, March, 1986

Second Workshop on the Modelling of Chemical Reaction Systems (plenary speaker),
University of Heidelberg, Heidelberg, W. Germany, August, 1986

Department of Mathematics, Duke University, March, 1986

Division of Applied Mathematics, Brown University, April, 1986

Mathematisches Forschungsinstitut, Oberwolfach, W. Germany, July, 1987

Symposium on the role of applied mathematics in chemical engineering (in honor of Neal
Amundson), American Institute of Chemical Engineers National Meeting, New York,
November, 1987

Department of Chemical Engineering, Cornell University, May, 1988

Department of Mathematics, Ohio State University, November, 1988

Department of Chemical Engineering, Princeton University, April, 1989

S.C. Johnson Co. Research Laboratories, Racine, Wisconsin, September, 1989

Institute for Mathematics and its Applications, University of Minnesota, October, 1989

Society for Industrial and Applied Mathematics, Chicago, July, 1990 (invited lecture)

Mobil Research Laboratories, Paulsboro, New Jersey, March, 1990

Division of Applied Mathematics, Brown University, April, 1991

Department of Chemical Engineering, Princeton University, October, 1991 (Lecture in
honor of Roy Jackson's 60th birthday)

Department of Chemical Engineering, University of the Witwatersrand, Johannesburg,
South Africa, September, 1992 (3 lectures)

Department of Chemical Engineering, University of Natal, Durban, South Africa,
September, 1992

Department of Chemical Engineering, University of Cape Town, Cape Town, South Africa,
September, 1992

Department of Chemical Engineering, Stellenbosch University, Stellenbosch, South Africa,
September, 1992

Society for Natural Philosophy, Department of Mathematics, Carnegie Mellon University, April, 1993 (Lecture in honor of Walter Noll)

EIIPC Symposium, Anticipating the Year 2020, Tufts University, March, 1995.

Third SIAM Conference on Dynamical Systems, Snowbird, Utah, May, 1995 (Plenary Lecturer).

Department of Chemical Engineering, University of Massachusetts, March, 1996.

Department of Chemical Engineering, University of Minnesota, September, 1996 (Special invited lecture in honor of Rutherford Aris's retirement).

Department of Chemical Engineering, North Carolina State University, October, 1996.

Department of Chemical Engineering, University of California at Santa Barbara, October, 1996.

Department of Chemical Engineering, University of Wisconsin, January, 1997.

Department of Chemical Engineering, Ohio State University, February, 1997.

Department of Chemical Engineering, McMaster University, March, 1997

John von Neumann Memorial Lecture in Theoretical Biology, Institute for Advanced Study, Princeton, N.J., March, 1997.

Department of Chemical Engineering, Princeton University, April, 1998 (Special lecture in honor of Roy Jackson)

Department of Chemical Engineering, University of Cincinnati, December, 1998.

National Science Foundation Workshop, Breckenridge, Colorado, July, 1999.

Winter 2000 Workshop on Biophysics: Genetic and Biochemical Networks, Aspen Center for Physics, Aspen, Colorado, January, 2000.

Department of Mathematics (Center for Nonlinear Science), Carnegie Mellon University, March, 2001 (2 lectures)

Department of Chemical Engineering, Massachusetts Institute of Technology, April, 2001.

Department of Mathematics, Duke University, May, 2002.

Department of Chemical Engineering, University of Minnesota, October 2002.

Department of Systems Biology, Harvard University Medical School, November, 2003.

Physics – Biology Seminar, Rockefeller University, April, 2004.

Department of Chemical Engineering, City College of the City University of New York, April, 2004.

Department of Mathematics, Georgia Institute of Technology, October, 2004.

Department of Mathematics, University of North Carolina at Chapel Hill, December, 2004.

Department of Chemical Engineering, California Institute of Technology, May, 2005.

Departments of Mathematics & Chemical Engineering - 3 lectures (The Amundson Lectures), University of Houston, December, 2005.

Department of Molecular Cell Biology, Weizmann Institute of Science, January, 2006

Department of Chemical Engineering, The Technion, Israel, January, 2006.

Fields Institute, Toronto, Canada, May, 2006

Department of Mathematics, University of Pittsburgh, October, 2006.

Department of Mathematics, Ohio University, October, 2006.

Lecture in honor of Neal Amundson's 90th birthday, AIChE National Meeting, San Francisco, November, 2006.

Department of Systems Biology, Harvard Medical School, February, 2007.

Institute for Mathematics and its Applications, University of Minnesota, March, 2007.

Courant Institute of Mathematical Sciences (two lectures), April, 2007.

Department of Biological Engineering, Massachusetts Institute of Technology, April, 2007.

Graduate Program in Bioinformatics, Boston University, May, 2007.

Synthetic Biology 3.0, Swiss Federal Institute of Technology, Zurich, Switzerland, June, 2007.

Department of Molecular Cell Biology, Weizmann Institute of Science, June, 2008.

Department of Chemical Engineering, Imperial College (London), June, 2008.

Department of Chemical Engineering, University of Kentucky, September, 2008.

Department of Chemical Engineering, Princeton University, October, 2008.

Synthetic Biology Workshop, Groningen, Netherlands, November, 2008.

Department of Systems Biology, Harvard Medical School, January, 2009.

Department of Chemical Engineering, Purdue University, March, 2009,

Department of Chemical Engineering, Tufts University, April, 2009.

Emergence in Chemical Systems 2.0, NSF-sponsored conference at the University of Alaska - Anchorage, June, 2009.

Department of Systems Biology, Harvard Medical School, August, 2009.

Department of Chemical Engineering, University of California — Santa Barbara, April, 2010.

Wilhelm Lectures, Department of Chemical Engineering, Princeton University, October, 2011. [2 Lectures]

Center for Nonlinear Studies, Los Alamos National Laboratories, April, 2012.

Cold Springs Harbor Laboratory, August, 2012. [2 Lectures]

Institute Lecture, Austria Institute of Science and Technology, Vienna, Austria, May, 2013.

Cold Springs Harbor Laboratory, August, 2013. [3 Lectures]

Department of Mathematics, West Virginia University, April, 2014

Department of Molecular Cell Biology, Weizmann Institute of Science, June, 2015

Department of Chemical Engineering, Princeton University, November, 2018 (William Pierce Field Fund Lectures [4 Lectures]).