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## VITA

**Karl Gustafson**

## EXPERIENCE:

## (i) EDUCATIONAL DEGREES:

B.S.	University of Colorado	1958 (Engineering Physics, Applied Mathematics)
B.S.	University of Colorado	1958 (Business Finance)
Ph.D.	University of Maryland	1965 (Mathematics)

## (ii) PROFESSIONAL POSITIONS HELD:

1. Instructor, Department of Applied Mathematics, University of Colorado, 1958–1960.
2. Physicist, Mathematician, GS 7,9,11, U.S. Naval Research Laboratory, Washington, D.C., 1959, 1960–1963.
3. Research Associate, Inst. Fluid Dynamics and Applied Mathematics, University of Maryland, 1963–1965.
4. NSF–NATO Postdoctoral Fellow, Institut Battelle, Geneva, and Instituto Matematico, Rome, 1965–1966.
5. Visiting Fellow, Forschungsinstitut fur Mathematik, ETH–Zurich, Summer, 1966.
6. Assistant Professor, Department of Mathematics, University of Minnesota, 1966–1968.
7. Visiting Fellow, Advanced Studies Center, Institut Battelle, Geneva, January–September, 1967.
8. Associate Professor, Department of Mathematics, University of Colorado, 1968–1973.
9. Invited Professor and 3<sup>ieme</sup> Lecturer, Département de Mathématiques, Ecole Polytechnique Fédérale, Lausanne, 1971–1972. Invited Professor, Institute of Theoretical Physics, University of Geneva, 1971–72.
10. Professor, Department of Mathematics, University of Colorado, 1973–present.
11. Invited Professor and 3<sup>ieme</sup> Cycle Lecturer, ETH–Lausanne, Summer Semester, 1976.
12. Invited Professor, University of Paris XI, 1978. Invited Professor, Inst. Theo. Phys., University of Louvain, 1978.
13. Invited Researcher, Zentrum fur Interdisziplinäre Forschung, Universität Bielefeld, Special Year on Properties and Reactions of Isolated Molecules and Atoms, 1979–80.
14. Faculty Research Fellow, University of Colorado, 1971–72, 1978–79, 1987–88.
15. Invited Professor, Moscow State University, May 1992; January 1993.
16. Honorary Member, International Solvay Institutes, ULB, Bruxelles, 1995–2004.
17. Founding Member, NSF Optoelectronic Computing Systems Center, University of Colorado, 1988–2000.
18. Member, Colorado Center for Chaos and Complexity, University of Colorado, 1996–2004.
19. Founding Member, Center for Neuroscience, University of Colorado, 1999–2005.
20. Invited Professor, Applied Mathematics Division, Université de Bordeaux, May–June, 2000.
21. Invited Professor, University of Thessaloniki, Lectures in May, 2011, 2012, 2014.

## (iii) ADMINISTRATION

Head, Mathematics, D-825 Computer Design Project,  
 Naval Research Laboratory, Washington, DC, 1960–63.  
 Scientific Officer, Ionospheric Propagation (with National Bureau of Standards),  
 1962–63.  
 Director, Mathematical Physics Ph.D. Program, University of Colorado, 1969–1970,  
 1974–1976, 1989–1999.  
 Chair, Ulam Chair Committee, Department of Mathematics, 1977–78, 1982–84.  
 Chair, Condon Memorial Lecture in Chemistry, Nobel Laureat I. Prigogine, Boulder, 1979.  
 Chair, VIIth International Congress on Mathematical Physics, Boulder, 1983.  
 Chair, Conference on Mathematical Physics, American Mathematical Society Meeting,  
 Boulder, 1980.  
 Initiator & Developer, University of Colorado Applied Mathematics Ph.D. Program, 1980–87.  
 Chair, IMACS Technical Committee 20: Computational Physics 1988–1996.  
 Chair, 1st IMACS International Conference on Computational Physics, Boulder, 1990.  
 Administrator Appraisal Program (creation, implementation), BFA, 1990–1997.  
 Chair, Administrator Appraisal Program, Boulder Faculty Assembly, 1996–1997.  
 Executive Committee, Boulder Faculty Assembly, 1996–1997.  
 CoDirector, Actuarial Studies and Quantitative Finance Program, 2007–2011.  
 CoResponsible, Establishment of Burnett Meyer Endowment and the Meyer Committee, 2007–  
 2012

## (iv) ADDITIONAL PROFESSIONAL EXPERIENCE

- (a) *Government–Industrial Experience.* Naval Research Laboratory, Washington, D.C., Radio Division, Countermeasures Branch, Intercept and Data Processing Section (Summer 1959; 1960–63). The problem was design and implementation of a large scale computer system into an active naval operation. The duties included: (1) management of all programming and mathematical aspects of the evolving system; (2) supervision of (then) current naval use of a smaller prototype system; (3) Scientific Officer for an ionospheric propagation research contract with N.B.S., Boulder; (4) participation in hardware and software specification, bidding thereupon, monitoring of the chosen contractor thereafter. The computer work included: (1) 3 coupled Royal–McBee LBP-30 computers, the Burroughs D-825 configuration, a T.R.W. microprogrammable computer, the NRL Narec computer; (2) machine language programming on all of the above; (3) design of compiler and executive programs for the D-825 system. The mathematical work included: (1) mathematical descriptions of a non-spherical earth, geodesic and mapping questions thereupon; (2) humanly and electro-magnetically biased statistical distributions, factor analysis thereof; (3) error correcting codes, choice thereof as a function of channel characteristics; (4) approximation of elementary transcendental functions by continued fractions. The security clearances required were Confidential, Secret, Top Secret. This work was successful and received the Presidential Service Award. (I wrote the software for the world’s first electronic intelligence satellite.)
- (b) *Consultant.* Institut Battelle, 1971; Los Alamos Scientific Laboratory, 1971; Springer–Verlag, 1977; La Jolla Institute, 1978 to 1985; Boeing Computer Services (joint grant), 1980–1984; NASA Lewis Research Center, 1989; Asea Brown Boveri Corp, 1989, 1990, 1992, 1994, 1996; Education Ministry, Colombia, 1990; Front Range Scientific Computing, 1993; Quality Data Management, 1996.

## BOOKS PUBLISHED:

1. *Positive (noncommuting) operator products and semigroups*, Battelle Institute, Geneva, 1967, pp. 22.
2. *Introduction to Partial Differential Equations and Hilbert Space Methods*, Wiley, New York, 1980, pp. 285.
3. *Quantum Mechanics in Mathematics, Chemistry, and Physics*, Plenum, New York, 1981 Springer, 2014, pp. 506.
4. *Introduction to Partial Differential Equations and Hilbert Space Methods*, Yeh Yeh Publishers, Taipei, Taiwan, 1983, pp. 285.
5. *Mathematical Physics VII*, North Holland, Amsterdam, 1984, pp. 715.
6. *Introduction to Partial Differential Equations and Hilbert Space Methods*, 2nd edition, Wiley, New York, 1987, pp. 438.
7. *Proceedings IMACS 1st International Conference on Computational Physics*, University of Colorado, Boulder, 1990, pp. 376.
8. *Vortex Methods and Vortex Motion*, SIAM, Philadelphia, 1991, pp. 227.
9. *Computational Physics*, North Holland, Amsterdam, 1991, pp. 341.
10. *Applied Partial Differential Equations. 1*, Kaigai Publishers, Tokyo, Japan, 1991, pp. 247.
11. *Applied Partial Differential Equations. 2*, Kaigai Publishers, Tokyo, Japan, 1992, pp. 235.
12. *Introduction to Partial Differential Equations and Hilbert Space Methods*, 3rd edition, International Journal Services, India, 1993, pp. 460.
13. *Lectures on Computational Fluid Dynamics, Mathematical Physics, and Linear Algebra*, Kaigai Publishers, Tokyo, Japan, 1996; World Scientific, Singapore, 1997, pp. 169.
14. *Numerical Range: The Field of Values of Linear Operators and Matrices*, Springer, Berlin, 1997, pp. 205.
15. *Partial Differential Equations and Hilbert Space Methods*, 3rd edition (Revised), Dover, Mineola, N.Y., 1999, pp. 472.
16. *The Crossing of Heaven: Memoirs of a Mathematician*, Springer Heidelberg, 2012, pp. 192.
17. *Antieigenvalue Analysis*, World-Scientific, Singapore, 2012, pp. 258.

## PUBLICATIONS:

1. *The Case Sheet*, Naval Res. Lab. Memorandum Report **1189** (1961), pp. 12.
2. *Project Bullseye Report No. 3*, Naval Res. Lab. Memorandum Report **1329** (1962), pp. 36.
3. *Mathematical Analysis of Direction Finding*, Naval Res. Lab. Formal Report **5742** (1962), pp. 109.
4. *Nonlinear, Nongaussian, and Nonindependent Estimation and Conditional Confidence Regions*, Naval Res. Lab. Formal Report **5994** (1963), pp. 28.
5. *Project Bullseye Report No. 4*, Naval Res. Lab. Formal Report **6006** (1963), pp. 27. (with B. Wald).
6. *Ionospheric Tilt Correlations Between Distinct Propagation Paths over a 22 Month Period*, Naval Res. Lab. Formal Report **6007** (1964), pp. 153. (with K. Morin).
7. *A priori bounds with applications to integrodifferential boundary problems*, Inst. Fluid Dynamics and Applied Math., Tech. Note BN-389, University of Maryland (1965), pp. 88. Dissertation Advisor: L. E. Payne.
8. *A perturbation lemma*, Bull. Amer. Math. Soc. **72** (1966), 334–338.
9. *Stability inequalities for semi-monotonically perturbed nonhomogeneous boundary problems*, SIAM J. Applied Math. **15** (1967), 368–391.
10. *Inequalities for nonlocal parabolic and higher order equations*, SIAM Review **9** (1967), 531–541. (with V. Sigillito).
11. *A Note on left multiplication of semi-group generators*, Pacific J. Math. **24** (1968), 463–465.
12. *The angle of an operator and positive operator products*, Bull. Amer. Math. Soc. **74** (1968), 488–492.
13. *Positive (noncommuting) operator products and semigroups*, Math. Zeitschrift **105** (1968), 160–172.

14. *Compact-like operators and the Eberlein theorem*, Amer. Math. Monthly **75** (1968), 958–964.
15. *State diagrams for Hilbert space operators*, J. Math. and Mech. **18** (1968), 33–46.
16. *A min–max theorem*, Amer. Math. Soc. Notices **15** (1968), p. 799.
17. *On the essential spectrum*, J. Math. Anal. Applic. **25** (1969), 121–127. (with J. Weidmann).
18. *Doubling perturbation sizes and preservation of operator indices in normed linear spaces*, Proc. Camb. Phil. Soc. **66** (1969), 281–294.
19. *On the cosine of unbounded operators*, Acta. Sci. Math. **30** (1969), 33–34. (with B. Zwahlen).
20. *Some perturbation theorems for nonnegative contraction semi-groups*, J. Math. Soc. Japan **21** (1969), 200–204. (with Ken-iti Sato).
21. *On projections of self-adjoint operators and operator product adjoints*, Bull. Amer. Math. Soc. **75** (1969), 739–741.
22. *A simple proof of the Toeplitz–Hausdorff Theorem for linear operators*, Proc. Amer. Math. Soc. **25** (1970), 203–204.
23. *Invited Book Review, “Elements of Functional Analysis,”* I. J. Maddox, Cambridge Univ. Press, Cambridge, 1970; Amer. Math. Monthly **78** (1971), 316–317.
24. *A branching analysis of the Hartree equation*, Rend. Mat. **4** (1971), 723–734. (with D. Sather).
25. *Antieigenvalue inequalities in operator theory*, Inequalities III (O. Shisha, ed.), Academic Press (1972), 115–119.
26. *Multiplicative perturbation of semigroup generators*, Pac. J. Math. **41** (1972), 731–742. (with G. Lumer).
27. *Necessary and sufficient conditions for Weyl’s theorem*, Michigan Math J. **19** (1972), 71–81.
28. *Multiplicative perturbation of nonlinear  $m$ -accretive operators*, J. Funct. Anal. **10** (1972), 149–158. (with B. Calvert).
29. *Large nonlinearities and monotonicity*, Archive Rat. Mech. and Anal. **48** (1972), 109–122. (with D. Sather).
30. P. Butzer, J. P. Kahane, B. Sz. Nagy, eds. (eds.), *Weyl’s theorems*, Linear Operators and Approximation, Proc. Oberwolfach Conf. 1971., International Series of Numerical Mathematics, Vol. 20, Birkhauser–Verlag, (1972), pp. 80–93.
31. *New and Unsolved Problems, 6.*, Linear Operators and Approximation, ISNM **20** (1972), p. 496.
32. *Large nonlinearities and closed linear operators*, Archive Rat. Mech. and Anal. **52** (1973), 10–19. (with D. Sather).
33. *Some essentially self-adjoint Dirac operators with spherically symmetric potentials*, Israel J. Math. **14** (1973), 63–75. (with P. Rejto).
34. *On operator radii*, Acta. Sci. Math. **36** (1974), 63–68. (with B. Zwahlen).
35. *On the absolutely continuous subspace of a selfadjoint operator*, Helv. Phys. Acta **47** (1974), 163–166. (with G. Johnson).
36. J. LaVita and J. P. Marchand (eds.), *Candidates for  $\sigma_{ac}$  and  $H_{ac}$* , Scattering Theory in Mathematical Physics, NATO Advanced Study Institute Series, Reidel, Doortrecht, (1974), pp. 157–168.
37. C. Enz and J. Mehra (eds.), *Fourier scattering subspaces*, Physical Reality and Mathematical Description, J. M. Jauch Festschrift Volume., Reidel, Doortrecht, (1974), pp. 277–285.
38. *On a principle of limiting adsorption for an arbitrary self-adjoint operator*, Proc. of the International Cong. of Math., Abstracts of Communications, Vancouver, (1974), p. 154.
39. *Correlations and evolution equations*, Sociedad Matematica Mexicana (1975), 243–252. (with B. Misra).
40. *On algebraic multiplicity*, Indiana Univ. Math. J. **25** (1976), 769–781.
41. *On ne peut pas creer l’excellence par l’administration*, Polyrama de l’Ecole Polytechnique Federale de Lausanne **32** (1976), 48–49. (In French)
42. *Canonical commutation relations of quantum mechanics and stochastic regularity*, Letters in Math. Phys. **1** (1976), 275–280. (with B. Misra).

43. *Asymptotic distribution of eigenvalues of product operators determining hydrodynamic stability*, Amer. Math. Soc. Notes **23** (1976), p. A-682.
44. *Numerical range and accretivity of operator products*, J. Math. Anal. Applic. **60** (1977), 693–702. (with D. Rao).
45. *Scattering theory and a principle of limiting absorption*, Proc. of the International Conf. on Operator Algebras, Ideals, and Their Applic. in Theoretical Physics, Leipzig, 1977, Teubner, Leipzig (1978), 335–349.
46. *Response to query 150*, S. Hastings, The Robin Boundary Condition, Amer. Math. Soc. Notes **27** (1979), 103, 228.
47. *Introduction to Partial Differential Equations and Hilbert Space Methods*, John Wiley and Sons, New York, (1980), pp. 285.
48. *Invited Book Review, “Unitary group representations in physics, probability, and number theory,”* George Mackey, Benjamin/Cummings, Reading, MA, 1978; Bull. Amer. Math. Soc. **2** (1980), 225–229.
49. *On converse to Koopman’s Lemma*, Physica **102A** (1980), 379–388. (with R. K. Goodrich and B. Misra).
50. *On the Eisenbud–Wigner formula for time delay*, Letters in Math. Physics **4** (1980), 381–385. (with K. Sinha).
51. H. Amann, N. Bazley, K. Kirchgassner (eds.), *Recent progress on the Nonlinear Hartree–Fock, Concentration–Diffusion, and Navier–Stokes equations*, Applications of Nonlinear Analysis in the Physical Sciences, Pitman, London, (1981), pp. 296–309.
52. *Weighted trigonometric approximations in  $L^2(\mathbb{R}^n)$* , Quantum Mechanics in Mathematics, Chemistry, and Physics, Plenum, N.Y., (1981), pp. 343–350. (with R. K. Goodrich).
53. *A study of the Helmholtz operator*, Quantum Mechanics in Mathematics, Chemistry, and Physics, Plenum, N.Y., (1981), pp. 107–120. (with G. Johnson).
54. *On the dimension of the finite difference approximations to divergence free vectors*, Quantum Mechanics in Mathematics, Chemistry, and Physics, Plenum, N.Y., (1981), pp. 125–132. (with R. Hartman).
55. *Irreversibility and stochasticity of chemical processes*, Quantum Mechanics in Mathematics, Chemistry, and Physics, Plenum, N.Y., (1981), pp. 203–210. (with R. K. Goodrich and B. Misra).
56. *On a generalized Weyl–Von Neumann converse theorem*, Quantum Mechanics in Mathematics, Chemistry, and Physics, Plenum, N.Y., (1981), pp. 289–306. (with M. Seddighin).
57. *Timestep control for the numerical solutions of initial-boundary value problems*, Quantum Mechanics in Mathematics, Chemistry, and Physics, Plenum, N.Y., (1981), pp. 407–414. (with J. Gary and H. Tadjeran).
58. Quantum Mechanics in Mathematics, Chemistry, and Physics, Plenum Press, N.Y., (1981), pp. 506. (with W. P. Reinhardt).
59. *Partial inner product spaces and semi-inner product spaces*, Advances in Mathematics **41** (1981), 281–300. (with J. P. Antoine).
60. *Weighted trigonometric approximation and inner-outer functions on higher dimensional Euclidean spaces*, Journal of Approximation Theory **31** (1981), 368–382. (with R. K. Goodrich).
61. I. Knowles and R. Lewis (eds.), *Higher Dimensional Spectral Factorization with Applications to Digital Filtering*, Spectral Theory of Differential Operators, North Holland, (1981), pp. 199–205. (with R. K. Goodrich).
62. *Exact solutions and ignition parameters in the Arrhenius conduction theory of gaseous thermal explosion*, Zeitschrift für angewandte Mathematik und Physik **33** (1982), 392–405. (with B. Eaton).
63. *The singular sequence problem*, Proceedings of the 8th Semester (Spectral Theory) of the International Banach Center, Warsaw, 1977, Banach Center Publications **VIII** (1982), 289–294.
64. J. Hinze (ed.), *Computation of solenoidal (divergence-free) vector fields*, Numerical Integration of Differential Equations and Large Linear Systems, Springer Lecture Notes in Mathematics #968, (1982), pp. 95–113. (with D. P. Young).
65. *Hybrid fast Poisson solvers for fluid dynamics*, Proc. 10th IMACS World Congress on System Simulation and Scientific Computation, Montreal, **1** (1982), 233–235.
66. J. Hinze (ed.), *Irreversibility questions in chemistry, quantum-counting, and time-delay*, Energy Storage and Redistribution in Molecules, Plenum Press, (1983), pp. 516–526.

67. *Divergence-free bases for finite element schemes in hydrodynamics*, SIAM J. Numer. Analysis **20** (1983), 697–721. (with R. Hartman).
68. *Calculation of critical branching points in two parameter bifurcation problems*, J. Comp. Phys. **50** (1983), 171–177. (with B. Eaton).
69. *Invited Book Review: “Non-Relativistic Quantum Dynamics,”* W. O. Amrein, Reidel, Dordrecht, 1981; Bull. Amer. Math. Soc. **8** (1983), 477–481.
70. R. W. Lewis (ed.), *Numerical calculation of critical parameters of thermal explosion*, Numerical Methods in Thermal Problems, Pineridge Press, Swansea, U.K., (1983), pp. 860–868.
71. C. Taylor, J. Johnson, W. Smith (eds.), *On the divergence-free (i.e., mass conservation, solenoidal) condition in computational fluid dynamics: how important is it?*, Numerical Methods in Laminar and Turbulent Flow, Pineridge Press, Swansea, U.K., (1983), pp. 617–626. (with K. Halasi).
72. *Regular representation and approximation*, Colloquia Mathematica Societatis Janos Bolyai **35** (1983), 539–550. (with R. K. Goodrich).
73. *A Banach–Lamperti theorem and similarity transformations in Statistical Mechanics*, Colloquia Mathematica Societatis Janos Bolyai **35** (1983), 567–579 (with R. K. Goodrich).
74. *Hybrid fast Poisson solvers for fluid dynamics, transonic flow, solenoidal projection, and the Navier-Stokes equations for general domains*, IMACS Transactions on Scientific Computation **1** (1983), 87–96.
75. *The RKNG (Rellich, Kato, Nagy, Gustafson) perturbation theorem for linear operators in Hilbert and Banach space*, Acta Sci. Math. **45** (1983), 201–211.
76. I. Knowles, R. Lewis (eds.), *Vorticity, incompressibility, and boundary conditions in the numerical solution of the Navier–Stokes equations*, Differential Equations, North Holland, (1984), pp. 257–264. (with K. Halasi).
77. *Mathematical Physics VII*, North Holland, Amsterdam, (1984), pp. 715; Also special volume *Physica A*, 124A, (1984), pp. 715. (with W. Brittin, W. Wyss).
78. P. Butzer, R. Stens, B. Sz. Nagy (eds.), *Graph theory in the approximation theory of fluid dynamics*, Anniversary Volume on Approximation Theory and Functional Analysis, International Series of Numerical Mathematics, Vol. 65, Birkhauser, Basel, (1984), pp. 511–520.
79. P. Butzer, R. Stens, B. Sz. Nagy (eds.), *Remarks (1983) on three new and unsolved problems (1971) in operator theory (1) Principal Axis (2) Numerical Range (3) Numerical Radius*, Anniversary Volume on Approximation Theory and Functional Analysis, ISNM 65, Birkhauser, Basel, (1984), pp. 602–607.
80. *On the structure of finite element solenoidal subspaces*, Constructive Theory of Functions, Bulgarian Academy of Sciences, (1984), pp. 382–391.
81. *Graph-theoretic Aspects of Flow Calculation Methods*, Fifth International Symposium on Finite Elements and Flow Problems, (G. Carey and J. T. Oden, eds.), Austin, Texas (1984), 219–224. (with R. Hartman).
82. *A new method for computing solenoidal vector fields on arbitrary regions*, International J. for Numerical Methods in Fluids **5** (1985), 763–783. (with K. Halasi and D. Young).
83. *The curl of graphs and networks*, Mathematical Modelling **6** (1985), 145–155. (with F. Harary).
84. *Graph theory and fluid dynamics*, SIAM J. on Algebraic and Discrete Methods **6** (1985), 643–656. (with R. Hartman).
85. R. Lewis, K. Morgan, J. Johnson, W. Smith (eds.), *Combustion and explosion equations and their calculation*, Chapter 7 of Computational Techniques in Heat Transfer, Pineridge Press, U.K., (1985), pp. 161–195.
86. *Principles of Electricity and Economics in Fluid Dynamics*, Numerical Methods for Partial Differential Equations **2** (1985), 145–157.
87. *Parallel methods for heterogeneous fluid structures*, Proceedings NSF Workshop on Parallel Processing, Univ. of Oklahoma, (1985), pp. 191–208. (with R. Leben).
88. *Factorization problems in fast elliptic solvers*, Numerical Methods and Applications, Bulgarian Academy of Sciences, (1985), pp. 330–335.
89. *Numerical methods for finding fluid fine structure*, Proceedings 11th IMACS World Congress **1** (1985), 5–8.
90. *Vortex dynamics of cavity flows*, J. of Computational Physics **64** (1986), 279–319. (with K. Halasi).

91. *Multigrid calculation of subvortices*, Applied Mathematics and Computation **19** (1986), 89–102. (with R. Leben).
92. *Spectral Approximation*, J. Approximation Theory **48** (1986), 272–293. (with R. K. Goodrich).
93. *On K-flows and irreversibility*, J. Statistical Physics **43** (1986), 317–320. (with R. K. Goodrich and B. Misra).
94. *Computation of the fine vortex structures of fluids*, Numerical Mathematics and Applications, IMACS Transactions on Scientific Computation **85** (1986), 355–363.
95. *Vortex separation and fine structure dynamics*, Applied Numerical Mathematics **3** (1987), 167–182.
96. *Kolmogorov systems and Haar systems*, Colloquia Mathematica Societatis Janos Bolyai **49** (1987), 401–416. (with R. K. Goodrich).
97. *Spectral estimation and factorization in higher dimensions*, Colloquia Mathematica Societatis Janos Bolyai **49** (1987), 383–399. (with R. K. Goodrich).
98. *Cavity flow dynamics at higher Reynolds number and higher aspect ratio*, J. of Computational Physics **70** (1987), 271–283. (with K. Halasi).
99. *Vortex Fission and Fusion*, Transactions of the Fourth Army Conference on Applied Mathematics and Computing, (1987), pp. 1143–1152.
100. *Intermittent Bifurcation of Vortex Flows*, Differential Equations and Mathematical Physics (I. Knowles, Y. Saito, eds.), Springer Lec. Notes in Math. 1285 (1987), 155–162.
101. *Introduction to Partial Differential Equations and Hilbert Space Methods*, 2nd Edition, John Wiley and Sons, New York, (1987), pp. 438.
102. *Vortex Subdomains*, 1st International Symposium on Domain Decomposition Methods for Partial Differential Equations (R. Glowinski, G. Golub, G. Meurant, J. Periaux, eds.), SIAM (1988), 370–380. (with R. Leben).
103. *Multigrid Localization and Multigrid Grid Generation for the Computation of Vortex Structures and Dynamics of Flows in Cavities and about Airfoils*, Multigrid Methods (S. McCormick, ed.), Dekker (1988), 229–250. (with R. Leben).
104. *Computational Vortex Dynamics: Some History, and Relation to Analytical Treatment*, 12th IMACS World Congress on Scientific Computation **2** (1988), 257–258.
105. *Vortex Dynamics of Viscous Flow Around Airfoils*, 12th IMACS World Congress on Scientific Computation **2** (1988), 267–270. (with R. Leben).
106. *Parameters of Hopf Bifurcation in Driven Cavity Flow*, 12th IMACS World Congress on Scientific Computation **2** (1988), 278–281. (with K. Halasi).
107. *Robust Multigrid Computation and Visualization of Separation and Vortex Evolution in Aerodynamic Flows*, 1st National Fluid Dynamics Congress, AIAA/ASME/SIAM/APS (1988), 178–184. (with R. Leben).
108. *Summary Report from the SIT Computer Aided Instruction Mathematics Subcommittee*, Fair Views **21** (1988), p. 14.
109. *Nonblowups, Periodicities, Vortex Shreddings in Combustion and Hydrodynamic Flows: A Conference Report*, Transactions of the Sixth Army Conference on Applied Mathematics and Computing, ARO Report 89-1, (1989), pp. 483–500. (with E. Ash, B. Eaton, K. Halasi, R. Leben).
110. *Controversies Concerning Finite/Infinite Sequences of Fluid Corner Vortices*, Contemporary Mathematics **99** (1989), 351–357. (with K. Halasi and R. Leben).
111. *Antieigenvalue Bounds*, J. Math. Anal. Applic. **143** (1989), 327–340. (with M. Seddighin).
112. *A Theory for Computational Vortex Dynamics*, IMACS Annals on Computing and Applied Mathematics **1** (1989), 265–269.
113. *Viscous Flow Around Airfoils*, IMACS Annals on Computing and Applied Mathematics **1** (1989), 139–144. (with R. Leben).
114. *Primacy and Recency Effects Due to Momentum in Backpropagation*, IEEE/INNS International Joint Conference on Neural Networks (1989), II-625. (with S. Goggin, K. Johnson).
115. *Counting the Number of Solutions in Combustion and Reactive Flow Problems*, Journal of Applied Mathematics and Physics **41** (1990), 558–578. (with E. Ash, B. Eaton).

116. *Preconditioned Conjugate Gradient Algorithm for Irregular Finite Element Grids*, Proceedings IMACS 1st International Conference on Computational Physics (1990), 60–66. (with N. Sobh).
117. *Computation of Hovering Mode Vortex Dynamics*, Proceedings IMACS 1st International Conference on Computational Physics (1990), 98–102. (with R. Leben).
118. *Periodicities, Intermittencies, and Criticalities in Driven Cavity and General Flows*, Proceedings IMACS 1st International Conference on Computational Physics (1990), 103–107. (with J. Goodrich, K. Halasi).
119. *Invited Book Review: “Stochastic Processes in the Neurosciences,”* Henry Tuckwell, SIAM Publications, Philadelphia, 1989; SIAM Review **32** (1990), 318–322.
120. *Hopf Bifurcation in Driven Cavity Flow*, J. Computational Physics **90** (1990), 219–261. (with J. Goodrich, K. Halasi).
121. *Iterative Methods for Neural Net Architectures*, Proc. Copper Mtn. Conf. on Iterative Methods (1990), 29 pp. (with S. Goggin, K. Johnson).
122. *Connectionist Nonlinear Over-Relaxation*, IEEE/INNS International Joint Conference on Neural Networks vol II (1990), 179–184. (with S. Goggin, K. Johnson).
123. *Reversibility in Neural Processing Systems*, Statistical Mechanics of Neural Networks, Springer Lecture Notes in Physics #368, (L. Garrido, ed.), (1990), pp. 269–285.
124. *Lectures on Computational Differential Equations*, Actas Seminario de Ecuaciones Diferenciales, UniValle, Colombia, (1990), pp. 12.
125. *Proceedings of the IMACS 1st International Conference on Computational Physics*, University of Colorado, Boulder, (1990), pp. 376. (with W. Wyss).
126. *Matemática Computacional y Matemáticas Computacionales*, Matematicas Enseñanza Universitaria **1** (1990), 3–13. (In Spanish)
127. *Vortex Methods and Vortex Motion*, SIAM Publications, Philadelphia, (1990), pp. 224. (with J. Sethian).
128. *Four Principles of Vortex Motion*, Vortex Methods and Vortex Motion, SIAM Publications, Philadelphia, (1990), pp. 95–141.
129. *Visualization and Computation of Hovering Mode Vortex Dynamics*, Vortex Methods and Vortex Motion, SIAM Publications, Philadelphia, (1990), pp. 143–169. (with P. Freymuth, R. Leben).
130. *The Flow Semigroup Approximation Problem*, Colloquia Mathematica Societatis Janos Bolyai **58** (1990), 343–354 (with K. Halasi).
131. *Antieigenvalues in Analysis*, Fourth International Workshop in Analysis and its Applications, Dubrovnik, Yugoslavia, June 1–10, 1990, (C. Stanojevic and O. Hadzic, eds.), Novi Sad, Yugoslavia (1991), 57–69.
132. *Time Asymptotic Flow Calculation*, Computer Physics Communications **65** (1991), 107–116. (with J. Goodrich, K. Halasi).
133. *Computation of Dragonfly Aerodynamics*, Computer Physics Communications **65** (1991), 121–132. (with R. Leben).
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#### EDUCATIONAL SERVICE:

##### (a) *Academic Visitor Supervision*

J. M. Jauch (1969, 1974), University of Geneva  
 Konrad Jorgens (1970, 1972-73), University of Munich  
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 Bruno Zwahlen (1977-78), E.T.H., Lausanne  
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##### (b) *Postdoctoral Supervision*

Dr. Bruce Calvert (1970), Ph.D., Chicago  
 Dr. Klaus Eckardt (1973-74), Ph.D., Munich  
 Dr. Peter Bader (1976-77), Ph.D., Lausanne  
 Dr. Jaime Arango (1990), Ph.D., Erlangen  
 Dr. Guido Sartoris (1994-96), Ph.D., Zurich

##### (c) *Doctoral Dissertations*

1. William Sikonia (Ph.D., 1970), *Essential, Singular, and Absolutely Continuous Spectra*.
2. Duggirala Rao (Ph.D., 1972), *Numerical Range and Positivity of Operator Products*.
3. Peter Bader (Ph.D., 1976), (with B. Zwahlen, ETH, Lausanne), *Méthode variationnelle pour l'équation de Hartree*.
4. Daniel Barraza (Ph.D., 1977), *Index Theory and Spectral Analysis*.
5. David Young (Ph.D., 1979), *Nonlinear Diffusion with Traveling Waves and Numerical Solutions*.
6. Hamid Tadjeran (Ph.D., 1980), (with J. Gary, Computer Science), *Boundary Approximation and Time Step Control in Iterative Improvement for the Numerical Solution of Partial Differential Equations*.

7. Morteza Seddighin (Ph.D., 1980), *Spectral and Numerical Range Theory for Banach Algebras, Forms and Unbounded Operators*.
8. Robert Hartman (Ph.D., 1981), *Divergence-free Bases for Finite Element Schemes and Numerical Solution of Laplace's Equation by Graph-theoretic Methods*.
9. Brian Eaton (Ph.D., 1983), (with R. Sani, Chemical Engineering), *The Galerkin Finite Element Method Applied to Viscous Incompressible Flows*.
10. Kadosa Halasi (Ph.D., 1983), *Numerical Solution of Two-Dimensional Potential Problems Using Fourier Analysis, Boundary Integral Equations and Near-Far Field Concepts*.
11. Robert Leben (Ph.D., 1986), (with C.Y. Chow, Aerospace Sciences), *Multigrid Calculations of Boundary-fitted Orthogonal Coordinates with Applications to Unsteady Flows*.
12. Ed Ash (Ph.D., 1988), *Counting the Number of Solutions in Reactive Flow Problems*.
13. Ioannis Antoniou (Ph.D., 1988), (with B. Misra, ULB, Brussels), *Internal Time and Irreversibility of Relativistic Dynamical Systems*.
14. Nahil Sobh (Ph.D., 1990), *Preconditioned Conjugate Gradient and Finite Element Methods for Massively Data-Parallel Architectures*.
15. Bonnie Shulman (Ph.D., 1991), (with E. Zweibel, Astrophysical Sciences), *Wave Propagation Through Inhomogeneous Media with Applications to Solar Corona Loops*.
16. Hussain Ojan (Ph.D., 1992), *Orthogonal Grid Generation in Three Dimensions*.
17. Shelly Goggin (Ph.D., 1992), (with K. Johnson, ECE), *Analysis and Optimization of Multilayer Neural Networks*.
18. John McArthur, (Ph.D., 1994), (with Robert Leben, Aerospace Engineering), *Operator Splitting in Hovering Mode Computation*.
19. John Davenport (Ph.D., 2007), *Analysis of American Options*.
20. Troy Seguin (Ph.D., 2008), *Risk Measures*.
21. Cui Cong (Ph.D., 2013), (with X.C. Cai, Computer Science), *Implicit Space-Time Domain Decomposition Methods for Stochastic Parabolic Partial Differential Equations*.
22. Ilias Gialampoukidis (Ph.D., 2014), (with I. Antoniou, Univ. of Thessaloniki), *The Time Operator and Age of Evolutionary Processes*.

(d) Countless Master's degrees (M.S., M.A.) supervised.

(e) Countless Ph.D. committees for other departments, especially Engineering.

#### REVIEWS AND REFEREEING:

- (a) Editor: Mathematics and Computers in Simulation (1990 to 2014)  
 Editor: International Journal on Scientific Computing and Modeling (1992–1999)  
 Guest Scientific Editor: Physica 124A (1984)  
 Guest Scientific Editor: Computer Physics Communications 65 (1991)
- (b) Evaluator of NSF, ARO, AFOSR, DOE, ISF, NRC, SDSC, NCAR, SWON, Marsden (N.Z.), NSERC (Canada), Fondecyt (Chile), The Croucher Foundation (Hong Kong), IAP (Belgium), Swedish Research Council, scientific proposals.
- (c) Reviewer, Mathematical Reviews (1966 to 2008).
- (d) Referee for the following journals:  
*Journal of Mathematics and Mechanics*  
*Journal of the London Mathematical Society*  
*Proceedings of the American Mathematical Society*  
*Michigan Mathematics Journal*  
*Mathematisches Annalen*



*Pacific Journal of Mathematics*  
*Rocky Mountain Mathematics Journal*  
*Journal of Mathematical Analysis and Applications*  
*Aequationes Mathematicae*  
*SIAM Journal of Mathematical Analysis*  
*Proceedings Royal Society of Edinburgh*  
*SIAM Journal of Numerical Analysis*  
*Indiana University Mathematics Journal*  
*Journal of Functional Analysis*  
*Journal of Approximation Theory*  
*Transactions of the American Mathematical Society*  
*Resultate der Mathematik*  
*Linear Algebra and Its Applications*  
*Houston Journal of Mathematics*  
*American Mathematical Monthly*  
*Journal of Combinatorial Theory*  
*International Journal of Mathematical Modelling*  
*Physica A*  
*International Journal Numerical Methods Fluids*  
*Journal of Mathematical Physics*  
*IMA J. of Applied Mathematics*  
*Journal of Computational Physics*  
*Transport Theory and Statistical Physics*  
*Mathematics and Computers in Simulation*  
*Computer Physics Communications*  
*Neural Networks*  
*IEEE Transactions on Neural Networks*  
*Monatshefte für Mathematik*  
*Computers and Fluids*  
*Physical Review Letters*  
*Physical Review*  
*SIAM Journal on Scientific Computing*  
*Journal of Physics D: Applied Physics*  
*Indian J. of Mathematics*  
*Numerical Linear Algebra with Applications*  
*Applied Mathematics Letters*  
*SIAM Journal on Matrix Analysis and Applications*  
*Journal of Operator Theory*  
*Metrika*  
*Biological Cybernetics*  
*Computers and Mathematics*  
*International Journal of Mathematics and Mathematical Sciences*  
*NeuroQuantology*  
*International Journal of Computational Fluid Dynamics*  
*Foundations of Physics Letters*  
*Progress in Computational Fluid Dynamics*  
*Mathematical Inequalities and Applications*  
*Tamkang Journal of Mathematics*  
*Journal of Fourier Analysis and Applications*

*Mathematisches Nachrichten*  
*J. of Applied Math. and Decision Sciences*  
*Annales des Sciences Mathématiques du Québec*  
*Proceedings of the Japan Academy*  
*Applicable Analysis and Discrete Mathematics*  
*Novi Sad J. of Mathematics*  
*Canadian Mathematics Bulletin*  
*International Journal of Theoretical Physics*  
*Journal of Inequalities and Applications*  
*International Journal of Quantum Information*  
*Chaos: An Interdisciplinary Journal of Nonlinear Science*  
*Numerical Methods for Partial Differential Equations*  
*IEEE Transactions on Automatic Control*  
*Foundations of Physics*  
*Acta Math Hungar*  
*Chaos, Solitons and Fractals*  
*J. of Statistical Computation and Simulation*  
*Annals of Physics*

## AWARDS AND RECOGNITION:

- (i) *RESEARCH GRANTS* (approximate \$ amounts in parentheses)
1. *NSF-NATO* Postdoctoral Fellowship, 1965–1966. (\$5000)
  2. *Forschungsinstitut Fellow*, summer 1966, ETH–Zurich. (\$2000)
  3. *Battelle Fellow*, January to September 1967, Geneva. (\$7000)
  4. *Investigator*, NSF GP7041X (with H. Weinberger) at University of Minnesota and University of Colorado, summer 1968. (\$4000)
  5. *Principal Investigator*, NSF GP9325 for research on Accretive Operators with Applications, November 1968–October 1969. (\$5400)
  6. *Principal Investigator*, NSF GP15239 for research on Perturbations of Operators with Applications to Nonlinear Partial Differential Equations, November 1969–October 1971. (\$15,500)
  7. *Co-Investigator*, NSF GP25689 (with Prof. Stanislaw Ulam) for Special Year for Mathematical Physics, January 1970–December 1970. (\$32,000)
  8. *Faculty Fellowship*, University of Colorado, 1971–1972.
  9. *Principal Investigator*, NSF GP15239A1 for research on Applications of Perturbations of Unbounded Operators, October 1971–June 1974. (\$18,100)
  10. *Principal Investigator*, NSF GP15239A2 for research on Applications on Unbounded Operators to Partial Differential Equations and Contraction Semigroups, June 1974–June 1975. (\$5,400)
  11. *Principal Investigator*, NSF MPS75–04765 for research on Applications of Perturbations on Unbounded Operators to Linear and Nonlinear Partial Differential Equations and Mathematical Physics, June 1975–November 1976. (\$26,900)
  12. *Principal Investigator*, NSF MCS75–04765 A01 for research on Operator Theory and its Applications to Fundamental Questions in Physics and Engineering, November 1976–October 1978. (\$18,700)
  13. *Invitee French Government*, 1 month, November 1978.
  14. *Faculty Fellowship*, University of Colorado, 1978–1979.
  15. *Invitee Institut Solvay*, 1 month, May 1979.
  16. *Principal Investigator*, National Center for Atmospheric Research Grants of Computing Resources, 17 CRAY units, January 1979–April 1985. (\$34,000)
  17. *Invited Research Fellow*, Special Year on Properties and Reactions of Isolated Molecules and Atoms, Center for Interdisciplinary Research, Bielefeld, Germany, 1979–1980.
  18. *Principal Investigator*, NSF Grant MCS–8012220 for Computational Studies and Software Development in Hydrodynamics, Concentration–Diffusion Equations, and Chemical Kinetics, 1980–1985. (\$188,317)
  19. *Principal Investigator*, NSF Grant MCS 8211597, VII<sup>th</sup> International Congress on Mathematical Physics, Boulder, Colorado, (with W. Brittin and W. Wyss), 1983–1984. (\$30,000)
  20. *Principal Investigator*. Grants associated with the Congress, see 19 above. IAMP, IBM, DU, U of C, IMU, IUPAP, other, 1983–1984. (\$35,000)
  21. *Principal Investigator*, NATO Grant 889/83 (with B. Misra and R. K. Goodrich) for research on Similarity Transformations Between Dynamical Semigroups with Applications to Irreversible Phenomena, 1984–1985. (\$4000)
  22. *Co-Investigator*, NSF Grant DMS 8404124 for Mathematical Sciences Research Equipment, (with J. Curry), 1984–1986. (\$45,000)
  23. *Co-Investigator*, NSF Grant Princeton Consortium for Supercomputing (with B. Ekstrand, M. Goldman, *et al.*), 1985–89. (\$1,000,000)
  24. *Principal Investigator*, Inst. Comp. Studies, CSU, CYBER 205 Resources, 1984–85. (\$15,000)
  25. *Co-Investigator*, NASA Num. Aerodynamical Simulator Supercomputing Grant, (with C.Y. Chow, R. Seebass, *et al.*), 1985–88. (\$500,000)

26. *Co-Investigator*, CDC Grant for Engineering Center for Computational Mechanics, (with R. Sani, K. Willam, *et al.*), 1985–86. (\$200,000)
27. *Principal Investigator*, NSF Grant MSM 8506320 for Engineering Computational Equipment, (with K. Willam, V. Saouma), 1985–1987. (\$76,000)
28. *Principal Investigator*, NAC Grant 14007, 1985–87. (\$80,000)
29. *Principal Investigator*, NSF Grant 14004, John Von Neumann Consortium for Scientific Computing, 1988–1990. (\$60,000)
30. *Principal Investigator*, NATO Grant RG 83/0889, 1986–1988. (\$6000)
31. *Faculty Fellowship*, University of Colorado, 1987–88.
32. *Principal Investigator*, NIH/BRSG Grant, 1987–88. (\$1500)
33. *Author*, John Wiley/Sons, 2 writing grants, 1986–1989. (\$4000)
34. *Principal Investigator*, NSF Grant, JVNC (Princeton), 1988–89. (\$10,000)
35. *Principal Investigator*, NASA–NAS Grant LE 39, 1988–1990 (with R. Leben). (\$80,000)
36. *Principal Investigator*, NASA–NAS Grant LE 77, 1988–1990 (with K. Halasi). (\$80,000)
37. *Principal Investigator*, NSF Research Center for Optoelectronic Computing Systems Grant ECD 9015128, 1990–1995. (\$22,000,000) (with T. Cathey, K. Johnson).
38. *Principal Investigator*, IMACS Conf. Grant, University of Colorado, 1990–1991. (\$5000)
39. *Principal Investigator*, NASA–NAS Grant LE–58, 1990–1991 (with R. Leben). (\$20,000)
40. *Principal Investigator*, NASA–NAS Grant LE–57, 1990–1991 (with K. Halasi). (\$20,000)
41. *Principal Investigator*, NASA–NAS Grant, 1991–1992 (with R. Leben). (\$20,000)
42. *Principal Investigator*, NASA–NAS Grant, 1992–1993 (with R. Leben). (\$20,000)
43. *Principal Investigator*, Nat. Acad. Sci./Nat. Res. Council Grant, 1992–1993. (\$3000)
44. *Principal Investigator*, Nat. Acad. Sci./AID/Russia Grant, 1992–1993. (\$10,000)
45. *Principal Investigator*, NATO Grant 920977, 1992–1995. (\$6000)
46. *Principal Investigator*, Fondation Les Treilles/Solvay Institut Grant, 1994. (\$2000)
47. *Principal Investigator*, Danish National Science Research Council Grant, 1994. (\$1600)
48. *Principal Investigator*, Junta Nacional Cientifica e Tecnologica Grant, 1994. (\$500)
49. *Principal Investigator*, Solvay Institute European Attraction Poles Grant, 1995. (\$3000)
50. Distinguished Lecture Series Grant, Japan, 1995. (\$5000)
51. *Principal Investigator*, NATO Grant 920977R, 1996–1997. (\$4000)
52. *Principal Investigator*, Fondation Les Treilles Grant, 1996. (\$2000)
53. *Principal Investigator*, Solvay Institute Grant, 1997. (\$2000)
54. *Keynote Lectures Grant*, Republic of Iran, 1998. (\$5000)
55. *Principal Investigator*, Solvay Institute Grant, 1998. (\$2000)
56. *Lecturer*, Marsden Grant, New Zealand, 1998. (\$3000)
57. *Principal Investigator*, Solvay Institute Grant, 1999. (\$1500)
58. *Principal Investigator*, Fondation Les Treilles Grant, 1999. (\$1200)
59. *Principal Investigator*, ABB Travel Grant, 1999. (\$6000)
60. *Professor Invité Grant*, Université de Bordeaux, summer, 2000. (\$6600)
61. *Collaborating Investigator*, EU Immunocomputing Project Grant, Solvay Institute, Brussels, 2000–2003. (\$1,500,000)
62. *Invited Speaker Grant*, CIRM, Trento, Italy, 2001. (\$1000)
63. *Invited Speaker Grant*, Hellenic (Greek) Government, Solvay 22 Congress on Physics, Delphi and Lamia, Greece, 2001. (\$2000)
64. *Invited Lecture Series Grant*, Scandinavia (4 countries), 2002, (\$6000)
65. *Beckman Institute Symposium Speaker Grant*, 2002. (\$1000)
66. *Principal Investigator*, NSF Grant DMS 0215228, 2002–2004 (with J. Curry). (\$75,000)
67. *CU Cost Sharing Grant* 153-5923, 2002–2004 (with J. Curry). (\$75,000)
68. *Invited Lecture Series Grants*, Germany/Switzerland, 2003. (\$4000)

69. *Invited Lectures Grant*, Vietnam, 2005. (\$1000)
70. *Research Award*, Department of Mathematics, 2006. (\$1000)
71. *Lecture Grant*, Canada, 2007. (\$500)
72. *Lecture Grant*, Sweden, 2007. (\$2500)
73. *Lecture Grant*, France, 2008. (\$1000)
74. *Lecture Grant*, Sweden, 2008. (\$2000)
75. *Lectures Grants*, Sweden and Slovakia, 2009. (\$2500)
76. *Lecture Grant*, China, 2010. (\$1000)
77. *Lecture Grant*. Greece. 2011. (\$5000)
78. *Lecture Grant*, Greece, 2012. (\$5000)
79. *ILAS Lecturer*, China, 2015. (\$1000)

\$ 24,829,117.00 Total Grant Sum brought to Univ. of Colorado by Karl Gustafson Individually or in Teams.

(ii) *INVITED LECTURES, TALKS, PAPERS GIVEN, SYMPOSIA, WORKSHOP PARTICIPANT*

1. Invited Colloquia given, University of Rome, Italy, 13 and 20 May 1966. Infinitesimal generators of semigroups.
2. NATO Summer Conference, Calculus of Variations, Bressanone, Italy, June 1966, participant.
3. Invited Colloquia given, University of Minnesota, 4 October 1966. Infinitesimal generators of quantum mechanical Markov processes.
4. Invited Colloquia given, University of Mainz, Germany, 30 May 1967. Perturbation of semigroup generators.
5. Invited Colloquia given, University of Heidelberg, Germany, 2 June 1967, Perturbation of semigroup generators.
6. Invited Colloquia given, University of Geneva, Switzerland, 17 June 1967. An answer to a question of E. Nelson.
7. Invited Colloquia given, Cornell University, 14 December 1967, Semigroup generators and Numerical Range.
8. Symposia on Nonlinear Functional Analysis, Chicago, April 1968, participant.
9. AMS meetings, Chicago, April 1968. Paper given: Multiplicative perturbation of semigroups.
10. Invited participant, University of Geneva, Scattering Theory Symposium, July 1968.
11. Invited conference speaker, Third Symposium on Inequalities, Los Angeles, September 1–10, 1969, Antieigenvalue Inequalities in Operator Theory.
12. University of Colorado Mathematics Colloquia given, 15 September 1969, A min–max theorem and moment problems.
13. Invited conference speaker, Indian Functional Analysis Conference (1969). (declined)
14. Invited conference speaker, Monterey Functional Analysis Conference (1969). (declined)
15. AMS Annual Summer Meeting, Eugene, Oregon, August 1969. Paper given: Polynomials of infinitesimal generators of contraction semigroups.
16. Invited conference speaker, RMMC Regional Conference on Functional Analysis, Bozeman, June 1970, Doubling Perturbation Sizes.
17. AMS Annual Meeting, Laramie, August 1970. Paper given: A branching analysis of the Hartree equation.
18. MRC Nonlinear Functional Analysis Symposium, Madison, April 1971, participant.
19. Invited Colloquia given, Los Alamos Scientific Laboratories, May 24, 1971. Application of initial value problem theory to bifurcation problems.

20. Invited conference speaker, RMMC Summer Seminar on Nonlinear Eigenvalue Problems, Santa Fe, June 1971. Application of monotone operator theory to quantum mechanics.
21. Invited conference speaker, Oberwolfach Nonlinear Conference, July 1971. (declined)
22. Invited conference speaker, Oberwolfach Scattering Theory Conference, June 1971. (declined)
23. Invited conference speaker, Research Conference on Numerical Ranges of Operators on Normed Spaces, Aberdeen, Scotland, July 1971, Numerical range for initial value problems.
24. Invited conference speaker, Conference on Linear Operators and Approximation, Oberwolfach, August 1971, Weyl's Theorems.
25. Invited Colloquia given, Inst. Battelle, Geneva, August 4, 1971, Perturbation of spectra.
26. Invited Lecturer, Semestre d'iver, 1971–72, Ecole Polytechnique Federale de Lausanne. *Operator Theory* (32 lectures). (1) Examples: linear and nonlinear operators; closed operators; differential operators. (2) Functional Analysis: Hahn–Banach Theorem; geometry of Banach spaces; projections. (3) Domains and Ranges of Operators: closed range theorem; index theory; open mapping theorem. (4) Special Types of Operators: selfadjoint; Fredholm; compact; continuous; algebras. (5) Boundary Value Problems: well-posed problems; Sobolev theory; Garding Inequality. (6) Eigenvalue problems: spectral theory; bifurcation theory; Lyapunov–Schmidt method. (7) Initial Value Problems: infinitesimal generators; Hille–Yosida theory; nonlinear semigroups. (8) Positivity: monotone operators; variational inequalities; cones.
27. Invited Lecturer, cours d'été 1972, EPFL Lausanne. Open Problems in Operator Theory (20 lectures). (1) Schauder base, (2) Deficiency index, (3) Gap dimension, (4) Continuity of the minimum modulus, (5) Ascent multiplicity, (6) Domains and category, (7) Form domains, (8) Topology of numerical ranges, (9) Operator radii, (10) Invariant subspaces.

Professor Invité, Seminaire d'analyse, 3<sup>ieme</sup> cycle, Switzerland, 5 Research Seminars given (see 28–32 which follow).

28. 14 December 1971, Some Nonlinear Eigenvalue Problems and Applications.
29. 21 December 1971, Some Nonlinear Initial Value Problems and Applications.
30. 18 January 1972, Multiplicative Perturbation of Initial Value Problems and Hammerstein Integral Equations.
31. 25 January 1972, Positive Operator Products, A Min–Max Theorem, and the Toeplitz–Hausdorff Theorem.
32. 1 February 1972, Recent Results on Weyl's Three Perturbation Theorems for the Essential Spectrum.
33. Invited Colloquia given, Aachen, Germany, February 7, 1972, Nonlinear initial value problems and nonlinear eigenvalue problems.
34. Invited Colloquia given, Frankfurt, Germany, February 8, 1972, Weyl's Theorems in linear spectral theory.
35. Invited Colloquia given, Munich, Germany, February 10, 1972, Weyl's Theorems.
36. Invited Colloquia given, Bochum, Germany, February 15, 1972, Weyl's Theorems and perturbation theory.
37. Invited Colloquia given, Stuttgart, Germany, May 15, 1972, Large nonlinearities and monotonicity.
38. Invited Boltzmann Lecturer, Graz, Austria, May 16, 1972. Essential self-adjointness of Dirac Operators.
39. Invited Colloquia given, Budapest, Hungary, May 18, 1972. Essential self-adjointness of Dirac Operators.
40. Invited Colloquia given, Szeged, Hungary, May 19, 1972. Essential self-adjointness of Dirac Operators.
41. Invited Colloquia given, Inst. Th. Physics, Geneva, May 26, 1972, Dirac Operators and the Rellich–Kato Theorem.

42. University of Colorado Mathematical Physics Colloquium, October 1972, Mathematical work on the Hartree equation existence problem.
43. University of Colorado Mathematical Physics Colloquium, November 1972, On the self-adjointness problem for the Dirac operator.
44. Invited conference speaker, NATO Advanced Study Institute on Scattering Theory, Denver, June–July 1973. Absolutely continuous spectra and scattering subspaces.
45. University of Colorado Mathematical Physics Colloquium, March 1974. Scattering subspaces.
46. International Congress of Mathematicians, Vancouver, August 21–29, 1974; paper given: On a principle of limiting absorption for an arbitrary selfadjoint operator.
47. III Mexico–U.S. Conference on Differential Equations, Mexico City, January 27–28, 1975. Paper given: Correlations and evolution equations.
48. Invited conference speaker, Conference on the Theory of  $C^*$  Algebras and its Applications to Physics, Bozeman, Montana, August 11–15, 1975. Some open operator theory problems in quantum mechanics.
49. Invited Colloquia given, Center for Particle Physics, Austin, Texas, December 3, 1975. On particle decay and stochastic regularity.
50. AMS Annual Meeting, San Antonio, January, 1976. Paper given: Particle decay and stochastic regularity.
- 51-62. 3<sup>ieme</sup> Cycle Suisse Romande Advanced Research Lectures, ETH–Lausanne, Summer Semester 1976, *Le Spectre Continu*: (1) Theorie spectral des operateurs autoadjoint, cinq versions; (2) Le problem de sous espace invariant et ce que  $\sigma_c$ ; (3) Processus stochastic regulier et des theoremes de type Paley–Wiener; (4) Relations canonical des commutators des mecanique quantique (SVN theorems) et processus stochastic (SSKW theorems); (5) Disintegration des particules (mesons); (6) Diffusion (scattering) et l’equation de Helmholtz; (7) Conditions de rayonnement de Sommerfeld, principe d’amplitude limitee, principe d’absorption limitee; (8) L’equation de Lippmann-Schwinger et la theorie de Kato–Kuroda; (9) Proprieté de “lifting,” resultats recent de Agmon et Hormander; (10) Un nouveau principe d’absorption limitee; (11,12) Problemes ouvert.
63. Invited Colloquia given, Inst. Theor. Physics, Geneva, May 28, 1976. Particle decay and stochastic regularity.
64. Invited Colloquia given, Koln, Germany, June 4, 1976. Particle decay and stochastic regularity.
65. Invited Colloquia given, Munich, Germany, June 8, 1976. Quantum Mechanics and Probability Theory.
66. 50th Anniversary of the Schrodinger Equation, Vienna, Austria, June 11–12, 1976, participant.
67. Invited Colloquia given, Centre Nationale de Recherche Scientific (CNRS), Marseille, France, June 22, 1976. Canonical commutation relations of regular stochastic processes.
68. 3rd International Workshop on Coulomb Systems and Statistical Mechanics, Lausanne, Switzerland, July 5–8, 1976, invited participant.
69. University of Colorado Mathematics Colloquia given, 20 September 1976. Particles and probability.
70. Invited Special Session Speaker, The Estimation of Eigenvalues, AMS Meeting, Albuquerque, New Mexico, November 19–20, 1976. Estimation of eigenvalue aggregates determining hydrodynamical stability.
71. Invited conference speaker, International Conference on Operator Algebras, Ideals, and Their Applications in Theoretical Physics, International Mathematical Union, Leipzig, September 1977. Scattering theory and limiting absorption principles. Session Chairman: Scattering Theory.
72. Invited Special Year Participant, 8th Semester (Spectral theory), Stefan Banach International Mathematical Center, Warsaw, Poland, 1977. (Visit declined, paper given). The singular

- sequence problem.
73. Workshop on Nonlinear Dynamics, La Jolla, California, December 27–30, 1977, invited participant.
  74. University of Colorado Mathematical Physics Colloquium, April 1978. The singular sequence problem.
  75. Invited Participant, NSF–CBMS Regional Conference on Scattering Theory, Salt Lake City, Utah, July 17–21, 1978.
  76. Invited Colloquia given, Inst. Physique Theorique, Louvain-la-neuve, Belgium, 12 October 1978. The singular sequence problem.
  77. Invited Colloquia given, Dept. of Mathematics, Louvain-la-neuve, Belgium, 19 October 1978. Stochastic processes and commutation relations.
  78. Invited Seminar given, Laboratoire de physique theorique et hautes energies, Orsay, France, 6 November 1978. The limiting absorption principle.
  79. Invited Workshop Participant, Conference on Mathematical Properties of Wave Functions, Zentrum fur Interdisziplinare Forschung, Bielefeld, Germany, 27–30 November 1978.
  80. Invited Colloquia given, Cornell University, 5 April 1979. Stochastic processes and group representations in higher dimensions.
  81. Invited Colloquia given, Hagen, Germany, May 3, 1979. The counter problem of quantum mechanics.
  82. Invited Colloquia given, Frankfurt, Germany, May 4, 1979. Three mathematical problems from the foundations of physics.
  83. Invited Colloquia given, University of Paris VI, France, May 10, 1979. Stochastic processes and commutation relations.
  84. Invited Workshop Participant, quantum Dynamics of Molecules, NATO Advanced Study Institute, Cambridge, England, 15–29 September 1979.
  85. Invited Conference Speaker, Applications of Nonlinear Analysis in the Physical Sciences, Bielefeld, Germany, 1–10 October 1979. Recent progress on the nonlinear equations of Hartree–Fock, Concentration–Diffusion, Navier–Stokes.
  86. Invited Participant, Unitary Group for Evaluation of Matrix Elements, Chemistry Conference, Bielefeld, November 1979 (declined).
  87. SIAM Fall Meeting, Denver, 12–14 November 1979, paper given. Computation of solenoidal (divergence-free) vector fields.
  88. Invited Talk, Western Reserve Academy, 20 November 1979. Partial differential equations.
  89. Special Session Organizer, Topics in Mathematical Physics, AMS Meeting, Boulder, 27–29 March 1980. Irreversibility and stochasticity of chemical processes.
  90. Invited Workshop Participant, Large linear systems, eigenvalues, and linear equations, Universitat Bielefeld, Germany, 23 April–2 May 1980. (declined, paper given) Computation of solenoidal divergence-free vector fields.
  91. Invited Seminar, The Boeing Company, Seattle, Washington, 12 June 1980. Some problems concerning the onset of instability toward turbulence, motion of fluid interfaces in diffusion processes, and rapid combustion.
  92. Invited Colloquia given, Koln, Germany, July 4, 1980. Some problems in mathematical chemistry.
  93. Invited Workshop Speaker, Energy scrambling in a molecule: how stationary are internal states?, Bielefeld, Germany, July 1980. Irreversibility questions in chemistry, quantum-counting, and time-delay.
  94. Invited Conference Speaker, International Conference on Functions, Series, and Operators in Honor of 100th Anniversary of Leopold Fejer and Frederic Riesz, Hungary, August 1980. A Banach–Lamperti theorem and similarity transformations in statistical mechanics.



95. Invited Conference Speaker, Conference on Long Term Prediction, March 16–19, 1981, Austin, Texas. Energy Scrambling in Molecules: What is Lost?
96. Invited Colloquia given, Toronto, Canada, March 23, 1981. Operator theory and statistical mechanics.
97. Invited Conference Speaker, International Conference on Spectral Theory of Differential Operators, Birmingham, Alabama, 26–28 March 1981. (declined, paper given) Higher dimensional spectral factorization with applications to digital filtering.
98. Invited Conference Speaker, International Conf. on Constructive Function Theory, Varna, Bulgaria, June 1–7, 1981. (declined)
99. Workshop Participant, Multigrid methods in Numerical Analysis, Palo Alto, California, 10–14 August 1981.  
Invited Lecturer, Banach Center 2nd Semester on Spectral Theory, Spring 1982, Warsaw, 5 lectures given (see 100–104):
100. Weyl–Von Neumann Perturbation Theory and Extensions, April 14, 1982.
101. The Singular Sequence Problem Revisited, April 15, 1982.
102. Nonperturbing algebras, April 16, 1982.
103. Nondeterministic Stochastic Process and Quantum Mechanics, April 19, 1982.
104. Spectral Factorizations in Higher Dimensions, April 20, 1982.
105. SIAM Conference on Linear Algebra, Raleigh, NC, 26–29 April 1982. Divergence-free bases for finite element schemes in hydrodynamics.
106. Invited Colloquia, ETH Lausanne, Switzerland, 1 July 1982. Exact solutions and ignition parameters in the Arrhenius conduction theory of gaseous thermal explosion.
107. Invited Conference Speaker, IMACS 10<sup>th</sup> World Congress on Systems Simulation and Scientific Computation, Montreal, Canada, 8–13 August 1982. Hybrid fast Poisson solvers for fluid dynamics.
108. University of Colorado Ulam Chair Colloquium, 16 November 1982. Graph theory and fluid hydrodynamics.
109. Special Session Speaker, Abstract Adjoints and Boundary Problems, AMS Annual meeting, Denver, 5–8 January 1983. Approximation of general boundary value problems by panel and capacitance matrix methods.
110. Invited Conference Speaker, International Conference on Differential Equations, Birmingham, Alabama, 21–26 March 1983. (declined, paper given) Vorticity, incompressibility, and boundary conditions in the numerical solution of the Navier–Stokes equations.
111. Session Chairman, Multigrid Conference, CSU, Copper Mountain, Colorado, April 6–8, 1983.
112. Participant, Conference on Large Scale Scientific Computation, 17–19 May 1983, MRC, Madison, Wisconsin.
113. Invited Seminar, Boeing Computer Services, Seattle, Washington, 20 May 1983. Graph-theoretic aspects of the French flow calculation methods.
114. SIAM National Meeting, Denver, Colorado, 6–8 June 1983. Graph theory and the Navier–Stokes equations.
115. Invited Conference Speaker, Special Anniversary Conference on Functional Analysis and Approximation, Oberwolfach, Germany, 31 July–6 August 1983. Graph theory in the approximation theory of fluid dynamics.
116. Invited Conference Speaker, International Conference on Numerical methods in Thermal Problems, Seattle, Washington, 5 August 1983. Numerical calculation of critical parameters of thermal explosion.
117. Invited Conference Speaker, International Conference on Numerical Methods in Laminar and Turbulent Flow, Seattle, Washington, 18 August 1983. On the divergence-free (i.e., mass conservation, solenoidal) condition in computational fluid dynamics: how important is it?

118. Co-Chairman, VII<sup>th</sup> International Congress on Mathematical Physics, Boulder, Colorado, August 1–10, 1983.
119. Invited Conference Speaker, Fifth International Symposium on Finite Element Methods in Flow Problems, Austin, Texas, 23–26 January 1984. Graph-theoretic aspects of flow calculation methods.
120. Invited Workshop Participant, NSF Workshop on Computing Resources in the Mathematical Sciences, Boulder, 2–3 February 1984.
121. Invited Participant, U. of Tennessee Space Institute Workshop on Computational Fluid Dynamics, 12–16 March 1984, Tullahoma, Tennessee.
122. Invited Seminar, Los Alamos Scientific Laboratory, Center for Nonlinear Studies, 3 April 1984. On the nonlinear equation  $-\Delta u = \lambda \exp f(u, \epsilon)$ .
123. Invited Seminar, Universität Koln, 16 May 1984. Combustion and explosion equations and their calculation.
124. Invited Seminar, INRIA, Paris, 24 May 1984. Combustion equations and the work of G. Bratu.
125. Invited Conference Speaker, International Conference on Constructive Theory of Functions, Varna, Bulgaria, 27 May 1984. On the structure of finite element solenoidal subspaces.
126. Invited Conference Speaker, International Conference on Numerical Methods and Applications, Sophia, Bulgaria, 27 August 1984. Factorization problems in fast elliptic solvers (declined, paper given).
127. Invited Colloquium Speaker, University of Alberta, Edmonton, Canada, January 17, 1985. Finding fluid fine features.
128. Participant, SPE–SEG–SIAM Meeting, 21–24 January 1985, Houston, Texas.
129. Invited Participant, 1<sup>st</sup> National Workshop on Parallel Processing Using the HEP, 20–21 March 1985, Norman, Oklahoma. Parallel methods for heterogeneous fluid structures.
130. Invited Conference Paper, Second Conference on Multigrid Methods, 1–3 April 1985, Copper Mountain, Colorado. Multigrid calculation of subvortices.
131. Participant, IMACS/ONR Workshop on Numerical Fluid Dynamics, 12–13 April 1985, Atlanta, Georgia. Vortex separation and fine structure dynamics.
132. Invited Congress Special Session Speaker, Numerical Methods for PDE's, 11<sup>th</sup> IMACS Congress, 5–9 August 1985, Oslo, Norway (declined, paper given).
133. Invited Speaker, Alfred Haar Memorial Conference, 11–17 August 1985, Budapest, Hungary. Kolmogorov systems and Haar systems.
134. Invited Conference Speaker, International Symposium on Computational Fluid Dynamics, Tokyo, Japan, September 1985. Computation of fluid recirculation dynamics (declined, paper given).
135. Invited Conference Speaker, NSF Special Year in Operator Theory, University of Indiana, Bloomington, Indiana, November 1985. (declined)
136. Invited Conference Speaker, UAB Conference on Differential Equations and Mathematical Physics, 3–8 March 1986, Birmingham, Alabama. Intermittent bifurcation vortex flows.
137. Invited Conference Speaker, Fourth Army Conference on Applied Mathematics and Computing, 27–30 May 1986. Vortex fission and fusion.
138. Invited Symposium Speaker, 1<sup>st</sup> International Symposium on Domain Decomposition methods for Partial Differential Equations, 7–9 January 1987, Paris, France. Vortex subdomains.
139. Invited Minisymposium Speaker, SIAM Conference on Numerical Combustion, 9–11 March 1987, San Francisco, California. Computation of criticality in combustion.
140. Invited Conference Paper, Third Copper Mountain Conference on Multigrid Methods, 6–10 April 1987, Copper Mountain, Colorado. Multigrid localization and multigrid grid generation for the computation of vortex structures and dynamics of flow in cavities and about airfoils.

141. Invited Conference Speaker, AMS/IMS/SIAM Joint Summer Research Conference on the Connection Between Infinite Dimensional and Finite Dimensional Dynamical Systems, 20–25 July 1987, Boulder, Colorado. Controversies concerning finite/infinite sequences of fluid corner vortices.
  142. Invited Seminar Paper, Boeing Company, Seattle, Washington, 13 August 1987. Multigrid computation of vortex splitting over airfoils.
  143. Invited Participant, Advances in Computational Modeling and Numerical Analysis, Conference in honor of Jim Douglas, Jr.'s Sixtieth Birthday, University of Chicago, 10–12 September 1987.
  144. Invited Participant, National Colloquium on Calculus for a New Century, 28–30 October 1987, National Academy of Sciences, Washington, D.C.
  145. Invited Colloquium Speaker, Indiana University, Bloomington, 25 February 1988. Vortex dynamics in cavities and lift over airfoils.
  146. Invited Sessions (3) Organizer, 12<sup>th</sup> IMACS World Congress on Scientific Computation, Computational Vortex Dynamics, Paris, 1988.
  147. Invited Participant, IMA Workshop on Signal Processing, June 27–July 10, 1988, Minneapolis, Minnesota.
  148. Invited Conference Speaker, Sixth Army Conference on Applied Mathematics and Computing, Boulder, 1 June 1988. Combustion and hydrodynamic flows.
  149. Invited Congress Speaker, 12<sup>th</sup> IMACS World Congress, Paris, July 1988. Computational vortex dynamics.
  150. Invited Congress Speaker, First National Fluid Dynamics Congress, Cincinnati, July 1988. Vortex dynamics in aerodynamic flows.
- State of Kansas Annual Mathematics Research Lecturer (see 151–152):
151. KSU–KU Annual Lecture, Kansas State University, October 4, 1988. Computational Fluid Dynamics.
  152. KSU–KU Annual Lecture, University of Kansas, October 6, 1988. Computational Fluid Dynamics.
  153. Speaker, Slow Pitch Colloquium, University of Colorado, 15 March 1989. Computational fluid dynamics: Its three facets.
  154. Invited Seminar Speaker, Inst. for Computational Mechanics in Propulsion, NASA Lewis Research Cntr., Cleveland, 28 April 1989. Vortex dynamics in aerodynamic flows.
  155. Invited Speaker, Asea Brown Boveri Corporation, Switzerland, 21 June 1989. Recent results in computational combustion and computational vortex dynamics.
  156. Contributed Paper, Workshop on Analytical Methods in Unsteady Separation, USARO and Ohio State University, 26 January 1990. Hovering mode vortex dynamics.
  157. Invited Special Session Speaker, Partial Differential Equations, American Mathematical Society, Regional Meeting, Manhattan, Kansas, March 1990. Bifurcation turning points in combustion equations.
  158. Invited Special Session Speaker, Numerical Analysis, American Mathematical Society, Regional Meeting, March 1990. Vortex dynamics of hovering mode.
  159. Invited Conference Speaker, Copper Mountain Conference on Iterative Methods, Copper Mountain, Colorado, April 1990. Iterative methods for neural net architecture.
  160. Invited Conference Speaker, Fourth International Workshop in Analysis and its Applications, Dubrovnik, Yugoslavia, June 1990. Antieigenvalues in analysis.
  161. Invited Conference Speaker, XI<sup>th</sup> Sitges Conference on Statistical Physics: Neural Networks, Barcelona, Spain, June 1990. Reversibility in neural processing systems.
  162. Conference Chair, IMACS 1<sup>st</sup> International Conference on Computational Physics, Boulder, June 1990. Opening Address.

Principal Lecturer, Conference on Differential Equations, UniValle 45-Year Celebration, Columbia, August 1990. 4 lectures give (see 163–166):

163. The Differential Equation of Bratu, Frank–Kamenetskii, Chandrasekhar, Emden, Poincaré, Liouville, Poisson–Boltzmann, Arrhenius, August 22, 1990.
  164. The Navier–Stokes Partial Differential Equations of Fluid Dynamics and their Numerical Computation, August 23, 1990.
  165. The Differential Equations for the Computation of Airfoil Flow, and First Computations of Dragonfly Aerodynamics, August 24, 1990.
  166. The Hodgkin–Huxley Differential Equations of Neurobiology, and Computation in Neural Nets, August 25, 1990.
  167. Invited Conference Speaker, Conference on Partial Differential Equations in honor of Prof. Lawrence Payne, Cornell University, October 1990. Dragonfly flight.
  168. Invited Colloquium Speaker, Indiana University, Bloomington, November 1990. Computation of dragonfly aerodynamics.
  169. University of Colorado Optical Computing Program Seminar, 1 April 1991. Artificial intelligence, intelligence, and neural nets.
  170. Conference Speaker, Seventh International Conference on the Numerical Analysis of Semiconductor Devices and Integrated Circuits, Copper Mountain, Colorado, April 1991. A semiconductor–combustion analogy.
  171. Participant, NATO Advanced Research Workshop on Homoclinic Chaos, Brussels, May 6–9, 1991.
  172. Invited Semester Lecturer, Banach Center 37<sup>th</sup> Semester, Numerical Analysis and Mathematical Modelling, Warsaw, May 13–17, 1991. Computational vortex dynamics.
  173. Invited Speaker, Solvay Seminar, Free University of Brussels, May 21, 1991. Inductive inference and neural nets.
  174. Invited Colloquium Speaker, University of Alberta, Edmonton, October 22, 1991. Dragonfly aerodynamics.
  175. Selected Spotlight Presentation, Neural Information Processing Systems Conference, Denver, Colorado, December 2–5, 1991. Human and machine ‘quick modelling.’
  176. University of Colorado Undergraduate Mathematics Club, February 20, 1992. Interdisciplinary mathematics: Risks and rewards.
  177. Workshop on Numerical Analysis of Nonlinear Optics, Moscow State University, Russia, May 13, 1992. Numerical versus analytical periodic solutions and bistabilities.
  178. Invited Lecturer, Moscow State University, Russia, May 18, 1992. Computation of hovering flight.
  179. Invited Seminar, ASCOM Corporation, Baden, Switzerland, June 15, 1992. Direction finding, parameter estimation, and neural nets.
- India Lectures (see 180–182):
180. Invited Speaker, IMACS International Symposium on Scientific Computing and Mathematical Modelling, Bangalore, India, December 10, 1992. High lift/high thrust hovering aerodynamics.
  181. Keynote Address, S. N. Bose Mathematical Physics and Applied Mathematics Platinum Jubilee Conference, Calcutta, India, December 15, 1992. Computational fluid dynamics.
  182. Invited Speaker, Indian Statistical Institute, Delhi, India, December 22, 1992. From probabilistic descriptions to deterministic dynamics.
  183. Kolmogorov Chair Lecture, Moscow State University, Russia, January 14, 1993. From probabilistic descriptions to deterministic dynamics — Theories of Kolmogorov and Prigogine.
  184. University of Colorado Kempner Colloquium, April 19, 1993. Mathematical computation of dragonfly aerodynamics.

185. Invited Speaker, Conference on Matrices and Graphs in honor of John Maybee, Boulder, May 7–8, 1993. Matrix trigonometry.
186. Invited Plenary Speaker, 2nd IMACS Conference on Computational Physics, St. Louis, October 9, 1993. Symmetry breaking in CFD: causes and consequences.
187. Keynote Address, Conference on Advanced Scientific Computing and Mathematical Modelling, Charleston, Illinois, December 3, 1993. Computation of hovering flight.
188. Conference Speaker, Colorado Conference on Iterative Methods, Breckenridge, Colorado, April 6, 1994. Computational trigonometry.
189. Conference Speaker, SIAM Conference on Emerging Issues in Mathematics and Computation from the Materials Sciences, Pittsburgh, Pennsylvania, April 19, 1994. Bistability and multistability.  
China Lectures (see 190–195):
190. Invited Lecturer, Department of Modern Mechanics, University of Science and Technology of China, Hefei, May 24, 1994. Hovering aerodynamics.
191. Invited Lecturer, Department of Mathematics, University of Science and Technology of China, Hefei, May 25, 1994. Antieigenvalues.
192. Invited Lecturer, Center for Mathematical Sciences, Chinese Academy of Sciences, Chengdu, June 13, 1994. Antieigenvalues in science and numerical analysis.
193. Invited Lecturer, Department of Applied Mathematics, University of Electronic Science and Technology of China, Chengdu, June 14, 1994. Neural networks in optoelectronics and inductive inference.
194. Invited Lecturer, Institute of Applied Physics and Computational Mathematics of China, Beijing, June 16, 1994. Recent advances in computational physics: Sixth generation computing, high resolution fluid dynamics, mathematical issues.
195. Invited Lecturer, Institute of Mechanics, Chinese Academy of Sciences, Beijing, June 17, 1994. Cavity flows and hovering flows.
196. Invited Speaker, Conference on Chaos, Time, and Resonances, Fondation des Treilles, Nice, France, July 1–3, 1994, Operator spectral states.
197. Invited Speaker, Third International Conference on Computational Physics, Copenhagen, Denmark, August 1–4, 1994. Biological aerodynamical systems.
198. Invited Speaker, Second Workshop on Numerical Ranges and Numerical Radii, Coimbra, Portugal, August 8–12, 1994. Operator trigonometry and numerical ranges.
199. Invited Seminar, ABB, Ltd., Baden, Switzerland, November 8, 1994. Antieigenvalues in Backpropagation Descent Algorithms.
200. Invited Seminar, Institute of Physical Chemistry, ETH, Zurich, Switzerland, November 9, 1994. Antieigenvalues for Physics and Chemistry.
201. Invited Seminar, International Solvay Institute for Physics and Chemistry, Brussels, Belgium, June 30, 1995. Rigged Spectral States.
202. Plenary Lecturer, Complexity and Chaotic Dynamics of Nonlinear Systems, Third Panhellenic Conference and Eighth Summer School, Xanthi, Greece, July 18, 1995. Chaos and Dragon Flies (Odonata).
203. Invited Speaker, Mechanical Engineering Seminar Series on Computational Fluid Dynamics, Bogazici University, Istanbul, Turkey, July 20, 1995. Hovering Aerodynamics.
204. Invited Principal Lecturer, International Conference on Nonlinear Dynamics, Chaotic and Complex Systems, Zakopane, Poland, November 7–12, 1995. Robustness of Backpropagation. (declined)  
Invited Speaker, Distinguished Lecture Series, Tokyo and Kyoto, Japan, October 25–November 6, 1995, 6 lectures given (see 205–210):

205. Department of Physics, University of Tokyo, Tokyo, October 26, 1995. Two New Results in Mathematical Physics: (a) A Gap Theory for Information Dimension, (b) The Time Operator of Wavelets.
  206. National Scientific Research Institute of Aerospace, Tokyo, October 27, 1995. Hovering Aerodynamics, Cavity Flow, and a New Notion of Rotational Release for Unsteady Computational Fluid Dynamics.
  207. Society for Applied Mathematical Analysis of Japan, Tokyo, October 28, 1995. Antieigenvalues and Their Applications.
  208. Department of Applied Physics and Department of Mathematics, Waseda University, Tokyo, October 30, 1995. Some Mathematical/Physical Issues in CFD.
  209. National Research Institute of Mathematical Sciences, University of Kyoto, Kyoto, November 2, 1995. From Probabilistic Descriptions to Deterministic Dynamics: Theories of Kolmogorov and Prigogine.
  210. National Research Institute of Mathematical Sciences, University of Kyoto, Kyoto, November 2, 1995. Qualitative Features of High Lift Hovering Aerodynamics.
  211. Invited Speaker, Conference on Algorithms and Computational Tools of Complex Systems, Brussels, Belgium, March 1–2, 1996. Wavelets, Time Operators, and Stochastic Processes.
  212. Invited Speaker, Conference on Algebraic Multilevel Iteration Methods with Applications, Nijmegen, Netherlands, June 13–15, 1996. Trigonometric Interpretation of Iterative Methods.
  213. Invited Speaker, ABB Corporate Research, Baden, Switzerland, June 26, 1996. Operator Trigonometry of Iterative Methods.
  214. Invited Speaker, Conference on Probabilistic Extensions of Classical and Quantum Dynamics, Les Treilles, France, July 4–10, 1996. De Rham Maps and Information Dimension.
  215. Invited Participant, Optical Computing Systems 1996 Industry Conference, Boulder, Colorado, November 12, 1996.
  216. Invited Speaker, Applied Mathematics Seminar, Pennsylvania State University, State College, November 15, 1996. Hopf Bifurcation of Fluid Flows.
  217. Invited Speaker, Conference on Hyperfunctions, Operator Theory, and Dynamical Systems, Brussels, Belgium, January 6–12, 1997. Semigroups and Antieigenvalues.
  218. Invited Speaker, Czech–U.S. Workshop on Iterative Methods and Parallel Computing, Milovy, Czech Republic, June 16–21, 1997. Operator Trigonometry of Domain Decomposition.
  219. Invited Speaker, Conference on Integrability and Chaos in Discrete Systems, Brussels, Belgium, July 2–6, 1997. Chaos in Discrete Learning Systems.
  220. Invited Speaker, Third IMACS International Symposium on Iterative Methods in Scientific Computation, Jackson Hole, Wyoming, July 9–12, 1997. Operator Trigonometry of Wavelet Frames.
  221. Invited Speaker, Tenth International Conference on Domain Decomposition Methods, Boulder, Colorado, August 10–14, 1997. Operator Trigonometry of Iterative Decomposition Methods.
  222. Invited Speaker, Applied Mathematics Seminar, Colorado State University, Ft. Collins, October 23, 1997. Operator Trigonometry of Iterative Methods.
  223. Invited Speaker, 1st International Conference on Unconventional Models of Computation, Auckland, New Zealand, January 5–9, 1998. Ergodic Learning Algorithms.
  224. Invited Speaker, 34th ANZIAM Conference, Coolangatta, Australia, February 7–11, 1998. Antieigenvalues and Applications.
  225. Invited Speaker, 9th Australian Conference on Neural Networks, Brisbane, Australia, February 11–13, 1998. Internal Dynamics of Backpropagation Learning.
- Invited Keynote Lectures, Iran National Seminar on Dynamical Systems, Isfahan, Iran, May 1–3, 1998. 5 lectures given (see 226–230).

226. Isfahan Institute of Technology, Iran, May 1, 1998. Recent Developments in Computational Fluid Dynamics.
227. Isfahan Institute of Technology, Iran, May 2, 1998. Recent Developments in Mathematical Physics.
228. Isfahan Institute of Technology, Iran, May 3, 1998. Recent Developments in Linear Algebra.
229. Invited Joint Colloquium, Departments of Chemical Engineering and Mechanical Engineering, Isfahan Institute of Technology, Iran, May 5, 1998. Near-chaos in High Re Cavity Flow and Low Re Hovering Flow.
230. Invited Seminar/Open Discussion, Department of Mathematics, Sharif University of Technology, Tehran, Iran, May 10, 1998. Current Trends in Advanced Partial Differential Equations Research.
231. Invited Speaker, IUTAM/IUGG Symposium on Developments in Geophysical Turbulence, Boulder, CO, June 16–19, 1998. Eddy-shed Pairs and the Onset of Flow Aperiodicity.
232. Invited Speaker, 16th International Conference on Numerical Methods in Fluid Dynamics, Arcachon, France, July 6–10, 1998. Capturing Correct Solutions in CFD.
233. Invited Plenary Speaker, IFAC Symposium on Large Scale Systems, Patras, Greece, July 15–17, 1998. Operator Trigonometry of Linear Systems.
234. Invited Minisymposium Speaker, IFAC Symposium on Large Scale Systems, Patras, Greece, July 17, 1998. Assigning Initial Weights in Feedforward Neural Networks.
235. Invited Speaker, Department of Applied Physics, Waseda University, Tokyo, Japan, October 29, 1998. Recent Results in the Anti-eigenvalue Theory and its Application.
236. Invited Speaker, Workshop on Wavelets and Wavelet-based Technologies, IBM, Tokyo, Japan, October 30, 1998. Wavelets as Stochastic Processes.
237. XXIst International Solvay Conference in Physics, Nara, Japan, November 1–5, 1998. The Geometry of Quantum Probabilities.
238. Invited Speaker, 1st International Conference on Semigroups of Operators: Theory and Applications, Newport Beach, CA, December 14–18, 1998. Semigroup Theory and Operator Trigonometry.
239. Invited Speaker, Mathematics Colloquium, University of Wyoming, Laramie, April 29, 1999. Antieigenvalues and Operator Trigonometry.
240. Invited Speaker, 1999 AMS–IMS–SIAM Summer Research Conference, Structured Matrices in Operator Theory, Numerical Analysis, Control, Signal and Image Processing, Boulder, CO, June 27–30, 1999. Operator Trigonometry and Its Applications.
241. Invited Speaker, International Conference on Probability and Irreversibility in Quantum Mechanics, Fondation Des Treilles, France, July 5, 1999. Probability, Geometry, and Irreversibility in Quantum Mechanics.
242. Invited Colloquium, Institute of Physical Chemistry, ETH Zurich, Switzerland, July 14, 1999. Antieigenvalues and Quantum Probability.
243. Invited Seminar, ABB Corporate Research, Baden–Dattwil, Switzerland, July 15, 1999. Black–Scholes Equations and Derivatives Pricing.
- Professor Invité Lectures, Université de Bordeaux, France, May 15–June 15, 2000, 4 lectures given (see 244–247):
244. Workshop on Penalization Method and No-Slip Flows, Université de Bordeaux, France, June 5, 2000. Pricing Financial Options and Penalty Methods.
245. Workshop on Penalization Methods and No-Slip Flows, Université de Bordeaux, France, June 5, 2000. On Vortex Dynamics.
246. Computational Fluid Dynamics Group Seminar, Université de Bordeaux, France, June 8, 2000. Quelques Problemes Ouvert de CFD.

247. Applied Mathematics Division Colloquium, Université de Bordeaux, France, June 8, 2000. A Computational Trigonometry.
248. Invited Participant, CEMRACS 2000 Workshop on Numerical Methods for Hamilton–Jacobi Equations and Applications, CIRM, Luminy, France, August 6–26, 2000.
249. Invited Speaker, Computational Methods in Decision-Making and Finance, 3ieme Cycle Romand Conference, Neuchatel, Switzerland, August 16, 2000. A 9th Derivation of the Black–Scholes Equation.
250. Invited Speaker, International Workshop on Parallel Matrix Algorithms and Applications, Neuchatel, Switzerland, August 18, 2000. Trigonometric Implications of Domain Decompsition Methods.
251. Conference Opening Address. Second International Conference on Unconventional Models of Computation, Brussels, Belgium, December 13, 2000. Everpresent Barrier Issues in 40 years of Parallel Computing.
252. Invited Speaker, Second International Conference on Unconventional Models of Computation, Brussels, Belgium, December 14, 2000. An Unconventional Computational Linear Algebra: Operator Trigonometry.
253. Invited Speaker, CIRM International Conference on Quantum Probability, Levico Terme (Trento) Italy, January 22, 2001. Operator Trigonometry and Quantum Probability.
254. Invited Faculty, APS student (UROP) trek to Nepal/Tibet, May 23 to June 23, 2001. Two faculty and nine students plus Sherpas and Tibetans. Kharta Valley to Rongbuk Monastery, Mt. Everest region.
255. Invited Speaker, International Interdisciplinary Workshop on Determinism, Rottach-Egern, Germany, June 4-8, 2001. Time-Space Dilations and Stochastic-Deterministic Dynamics (my paper was presented and discussed by others due to my absence in Tibet).
256. Invited Speaker, Conference on the Analytic Theory of Continued Fractions, Orthogonal Functions, Rational Approximation and Related Topics, Grand Junction, Colorado, August 9, 2001. Orthogonal Functions, Continued Fractions, Time Operators, and Inverse Problems.
257. Invited Lecture, XXII International Solvay Conference in Physics, Delphi, Greece, November 26-29, 2001. Bell’s Inequalities.
258. 22nd Solvay Congress on Physics, Lamia, Greece, 29 November 2001. Panel of 4 experts (Chiao, Gustafson, Prozik, Sudershan) to summarize the Congress for the press and for TV stations Star Channel and National Channel 3 of Greece. Quantum Computing.
259. Invited Speaker, Aristotle University of Thessaloniki, Greece, 30 November 2001. Operator Trigonometry and Its Applications.  
Scandinavian Lecture Series, Denmark, Sweden, Norway, Finland, May 12–June 12, 2002. 7 lectures given (see 260–266).
260. Roskilde University, Copenhagen, Denmark, May 14, 2002. The Story of Robin and Academic Politics 100 year ago.
261. Norwegian University of Science and Technology, Trondheim, Norway, May 23, 2002. Operator Trigonometry.
262. Institute of Information Technology, Uppsala University, Sweden, May 29, 2002. Operator Trigonometry of preconditioning, Domain Decomposition, Sparse Approximate Inverses, Successive Overrelaxation, Minimum Residual Schemes: More on the Geometry of Iterative Methods.
263. Angstrom Institute, Uppsala University, Sweden, May 30, 2002. Bell’s Inequalities.
264. International Conference on the Foundations of Probability and Physics, Vaxjo, Sweden, June 3, 2002. Bell’s Inequality and the Accardi–Gustafson Inequality.
265. International Conference on Partial Differential Equations, Karlskrona, Sweden, June 5, 2002. A Zeno Story.



266. University of Tampere, Finland, June 10, 2002. Operator Trigonometry of Statistics and Econometrics.
267. Symposium on Bell Inequalities, Beckman Institute, University of Illinois, October 22, 2002. The Geometry of Quantum Probability.  
Switzerland/Germany Lecture Series, May 10–27, 2003. 5 lectures given (see 268–272):
268. Asea Brown Boveri Ltd., Baden, May 13, 2003. Preconditioning and Overrelaxation for the Numerical Solution of Partial Differential Equations as Seen from the Geometric Viewpoint.
269. University of Fribourg, Switzerland, May 15, 2003. Antieigenvalues.
270. Institute of Theoretical Physics, University of Geneva, Switzerland, May 19, 2003. Old and New Results on the Zeno and Bell Problems of Quantum Mechanics.
271. Institut für Grenzgebiete der Psychologie und Psychohygiene (IGPP), Freiburg, Germany, May 22, 2003. Local Chaos in Machine and Human Cognition.
272. University of Freiburg/IGPP, Freiburg, Germany, May 23, 2003. A Zeno Alternative.
273. 2003 International Conference on Preconditioning Techniques for Large Sparse Matrix Problems in Scientific and Industrial Applications. Napa, California, October 29, 2003. Preconditioning, Inner Products, Normal Degree, Absolute Condition.
274. Invited Speaker, Quantum Structures 2004, University of Denver, July 17–22, 2004. Bell and Zeno.
275. Invited Presentation, Sigma Pi Sigma National Physics Honorary Quadrennial Congress, Joint with AIP/APS/SPS Regional Meeting, Albuquerque, New Mexico, October 14–16, 2004. Bell's Theorem and the Einstein Podolsky Rosen Dilemma.
276. Invited Speaker, 14th International Workshop on Matrices and Statistics, Auckland, New Zealand, March 30, 2005. The Geometry of Statistical Efficiency.  
Vietnam Lecture Series, June 1–17, 2005. 3 lectures given (see 277–279).
277. Invited Plenary Speaker, The Second International Conference on Abstract and Applied Analysis, Quy Nhon, Vietnam, June 4, 2005. Noncommutative Trigonometry.
278. Invited Speaker, Summer School on Harmonic, Wavelet and  $P$ -adic Analysis, Quy Nhon, Vietnam, June 10, 2005. Wavelets and Expectations.
279. Invited Speaker, Vietnamese Academy of Science and Technology, Institute of Mathematics, Hanoi, Vietnam, June 15, 2005. Noncommutative Operator Algebra and Bell Inequality.
280. Invited Speaker, Evolution Equations 2006, Mons, Belgium and Valenciennes, France, August 28–31, 2006. No Radial Symmetries in the Arrhenius–Semenov Thermal Explosion Equation.
281. Invited Speaker, Interdisciplinary Centre for Nonlinear Phenomena and Complex Systems, ULB, Brussels, August 30, 2006. Noncommutative Trigonometry and the Bell and Zeno Problems.
282. Invited Participant, Millenium Problem (Navier-Stokes) Workshop, Analytical and Computational Challenges of Incompressible Flows at High Reynolds Number, CSCAMM, University of Maryland, October 23–26, 2006.
283. Invited Speaker, AAAI Spring Symposium on Quantum Interaction, Stanford, March 27–29, 2007. Interconnections of Quantum, Machine, and Human Learning.
284. Invited Speaker, 16th International Workshop on Matrices and Statistics, Windsor, Canada, June 1–3, 2007. Operator Trigonometry of Hotelling Correlation, Frobenius Condition, Penrose Twister.
285. Participant, Richard Von Mises Lecture, Berlin, June 7, 2007, and Colloquium in honor of Hans Föllmer, Berlin, June 8–9, 2007.
286. Invited Speaker, International Conference on Quantum Theory: Reconsideration of Foundations–4, Växjö, Sweden, June 11–16, 2007. The Born Rule.

287. Invited Speaker, 1st International Workshop on Functional and Operatorial Statistics, Toulouse, France, June 19–21, 2008. The Operator Trigonometry in Statistics.
288. Invited Speaker, Sparse Matrix Days 2008, CERFACS, Toulouse, France, June 23–24, 2008. Normal Degree and Krylov Sequences.
289. Invited Speaker, Fifth Conference on Foundations of Probability and Physics, Vaxjo, Sweden, August 24–27, 2008. The Trigonometry of Twistors and Elementary Particles.
290. Invited Speaker, 5th International Conference on Quantum Theory: Reconsideration of Foundations, Vaxjo, Sweden, June 15–18, 2009. Trigonometry of Quantum States.
291. Invited Speaker, 18th International Workshop on Matrices and Statistics, Smolenice Castle, Slovakia, June 23–27, 2009. On my Min-Max Theorem (1968) and Its Consequences. Shanghai, China Lectures, June 4–15, 2010. 3 lectures given (see 292–294).
292. Plenary Lecture, IWMS 2010, Shanghai Finance University, June 6, 2010. Forty Years of Antieigenvalue Theory and Applications.
293. Invited Speaker, School of Mathematical Sciences, Shanghai University, June 10, 2010. Partial Differential Equations, A Trigonometry of Iterative Solvers, and Normal Degree.
294. Invited Speaker, Department of Mathematics, Fudan University, June 11, 2010. A Computational Trigonometry and Questions of Normal Degree. Greece Lectures, May 17–20, 2011, University of Thessaloniki. 4 lectures (see 295–298)
295. Lectures on Distributed Intelligent Systems: A Personal History: 1960–2010.
296. Military Networks. 1960. The World’s First Spy Satellite.
297. Human Networks. 1972. Human Trajectory Analysis. Neural Networks. 1992. Context.
298. Financial Networks, 2010. Speed of Light Arbitrage. Reasons for Financial Crashes. Sweden Lectures, June 12–21, 2011
299. Plenary Lecture, FPP6, Linneaus University, Vaxjo, June 16, 2011. Detailed Balance.
300. University of Stockholm, Department of Physics, June 20, 2011. Mutually Unbiased Bases.
301. Uppsala University, Department of Information Technology, June 21, 2011. Normal Recurrence Length and Gravitational Lensing. Greece Lectures, May 22–31, 2012, Thessaloniki. History of Internet and Electronic Finance (see 302–307)
302. Satellites (1960) and Microwave Communications.
303. ARPANET (1970) and Packet Switching.
304. TCP/IP Protocols (1980) and WWW.
305. Financial Exchanges (1990) and Computerized Trading.
305. Dark Pools and Hidden Trading.
307. High Frequency Trading and World-Wide Arbitrage.
308. Boulder Book Store, June 20, 2012. The Crossing of Heaven: Memoirs of a Mathematician.
309. Ball Aerospace & Technologies Corp., Boulder, Oct. 19, 2012. Parallel Computing Fifty Years Ago and the World’s First Spy Satellite.
310. Estes Valley Library, July 22, 2013. Climbs of my Youth—Early 1950s.
311. Invited Speaker, 22nd International Workshop on Matrices and Statistics, Fields Institute, Toronto, Canada, August 12–15, 2013. A New Financial Risk Ratio.
312. Keynote Lecture, 31st Annual Meeting of the Hellenic Mathematical Society, Veria, Greece, November 7–9, 2014. The Future of Mathematics: From the Pure-Applied Debate to Reality. [https:// www.youtube.com/watch?v=XOv9SJ3Q-WI](https://www.youtube.com/watch?v=XOv9SJ3Q-WI)

313. Roundtable, Challenges for Mathematics Research and Education in the Internationalized and Network Era, HMS 31st Meeting, Veria, Greece, November 8, 2014.
314. Opening Keynote Lecture, Quantum Probability and The Mathematical Modelling of Decision Making, Fields Institute, Toronto, Canada, March 9-11, 2015. The Importance of Imagination (or lack thereof) in Artificial, Human, Quantum Cognition and Decision-Making.
315. The ILAS Lecture, The 24th International Workshop on Matrices and Statistics, Haikou, Hainan, China, May 25-28, 2015. Antieigenvalue Analysis, Further Applications: Continuum Mechanics, Economics, Number Theory
316. Opening Keynote Lecture, The Second Shanghai Forum of Trade and Financial Statistics, Shanghai University of International Business and Economics, China, June 1, 2015. New Financial Risk Ratios and Portfolio Growth Angles.

OTHER:

(a) *Honors and Awards*

Eagle Scout, 1951.  
 Most Valuable Student Award, Boulder High School, 1953.  
 Chapter President, Sigma Pi Sigma, National Physics Honor Society, 1957–58.  
 Tau Beta Pi, National Engineering Honor Society, 1957.  
 Presidential Service Award (Team), NRL, 1962.  
 Research Society of America, Naval Research Laboratory, 1963.  
 NSF–NATO Postdoctoral Fellow, 1965–1966.  
 Best Teacher Award, The Working Press, April 1978.  
 Mentor, Outstanding May 1982 Graduate of the College of Arts and Sciences,  
 Michael Glassman, Summa Cum Laude Honors.  
 Faculty Research Fellow, University of Colorado, 1971–72, 1978–79, 1987–88.  
 The State of Kansas Annual Mathematics Research Lecturer, 1988–89.  
 The Keynote Lecturer, UniValle 45-Year Celebration, Rector’s Distinguished Service  
 Award, Colombia, 1990.  
 The Keynote Address, S. N. Bose Platinum Jubilee Conference, India, 1992.  
 The Kolmogorov Lecture, Russia, 1993.  
 China Lecture Series, 1994.  
 Distinguished Lecture Series, Tokyo/Kyoto, Japan, 1995.  
 Honorary Member, International Solvay Institutes of Physics and Chemistry, Brussels,  
 Belgium, 1995–2004.  
 The Annual Keynote Lectures, Iran National Seminar on Dynamical Systems, Iran, 1998.  
 Mentor, National Goldwater Scholarship Award, Veronika Furst, 1999–2001.  
 Professor Invité lectures, Bordeaux, France, 2000.  
 The Conference Opening Address, Unconventional Computing Methods, Belgium, 2000.  
 Scandinavian Lecture Series, Denmark/Sweden/Norway/Finland, 2002.  
 Switzerland/Germany Lecture Series, 2003.  
 Vietnam Lecture Series, 2005.  
 China Lectures, 2010, 2015.  
 Greece Lecture Series, 2011, 2012, 2014.

(b) *Professional Societies (Present or Past Member)*

American Mathematical Society  
 Research Society of America  
 International Association of Mathematical Physics

American Institute of Physics  
 Society for Industrial and Applied Mathematics  
 International Association for Mathematics and Computers in Simulation  
 American Geophysical Union  
 International Quantum Structures Association  
 Association for the Advancement of Artificial Intelligence  
 International Linear Algebra Society.

(c) *Literature Citations (Books Only)*

- M. Schechter, *Spectra of Partial Differential Operators*, Academic Press (1971).  
 A. Weinstein and W. Stenger, *Methods of Intermediate Problems for Eigenvalues*, Academic Press (1972).  
 H. Brezis, *Opérateurs Maximaux Monotones et Semigroupes de contractions dans les espaces de Hilbert*, North Holland/American Elsevier (1973).  
 F. Bonsall and J. Duncan, *Numerical Ranges II*, Cambridge University Press (1973).  
 N. Dunford and J. Schwartz, *Linear Operators III*, Wiley Interscience (1973).  
 J. La Vita and J. Marchand, *Scattering Theory in Mathematical Physics*, D. Reidel, Boston (1974).  
 W. N. Everett, *Spectral Theory and Differential Equations*, Springer (1975).  
 W. G. Faris, *Self-Adjoint Operators*, Springer (1975).  
 M. Reed and B. Simon, *Methods of Modern Mathematical Physics II*, Academic Press (1975).  
 V. Barbu, *Nonlinear Semigroups and Differential Equations in Banach Spaces*, Noordhoff, Leyden (1976).  
 F. Browder, *Nonlinear Operators and Nonlinear Equations of Evolution in Banach Spaces*, American Mathematical Society (1976).  
 T. Kato, *Perturbation Theory for Linear Operators*, 2nd Ed., Springer (1976).  
 V. G. Sigillito, *Explicit a priori Inequalities with Applications to Boundary Value Problems*, Pitman Publishing (1977).  
 W. Amrein, J. M. Jauch, and K. Sinha, *Scattering Theory in Quantum Mechanics*, Addison-Wesley (1977).  
 M. Reed and B. Simon, *Methods of Modern Mathematical Physics IV*, Academic Press (1978).  
 R. Richtmyer, *Principles of Advanced Mathematical Physics*, Springer (1978).  
 E. B. Davies, *One Parameter Semigroups*, Academic Press, London (1980).  
 H. Primas, *Chemistry, Quantum Mechanics, and Reductionism*, Lecture Notes in Chemistry 24, Springer, Berlin (1981).  
 W. Amrein, *Non-Relativistic Quantum Dynamics*, Reidel (1981).  
 O. Axelsson and V. Barker, *Finite Element Solution of Boundary Value Problems: Theory and Computation*, Academic Press (1984).  
 Jerome Goldstein, *Semigroups of Linear Operators and Applications*, Oxford Press (1985).  
 D. E. Edmunds and W. D. Evans, *Spectral Theory and Differential Operators*, Oxford University Press (1987).  
 J. Bebernes, D. Eberly, *Mathematical Problems from Combustion Theory*, Springer (1989).  
 E. Zeidler, *Nonlinear Functional Analysis and Its Applications*, Springer (1990).  
 C. A. J. Fletcher, *Computational Techniques for Fluid Dynamics*, 2nd Ed., Springer (1991), Vol. 1, Vol. 2.  
 A. J. Chorin and J. E. Marsden, *A Mathematical Introduction to Fluid Mechanics*, 3rd ed., Springer (1993).

- S. Haykin, *Neural Networks: A Comprehensive Foundation*, MacMillan, New York (1994).
- P. Gresho, R. Sani, *Incompressible Flow and the Finite Element Method*, Wiley, New York (1998).
- I. Stakgold, *Green's Functions and Boundary Value Problems*, 2nd Ed., Wiley, New York (1998).
- K. Engel and R. Nagel, *One Parameter Semigroups for Linear Evolution Equations*, Springer, Berlin (2000).
- T. Furuta, *Invitation to Linear Operators*, Taylor and Francis, London (2001).
- I. Prigogine, *Is Future Given?* World Scientific, Singapore (2003).
- A. Böttcher and S. Grudsky, *Spectral Properties of Banded Toeplitz Matrices*, SIAM Publications, Philadelphia (2005).
- L. Trefethen and M. Embree, *Spectra and Pseudospectra*, Princeton University Press (2005).
- E. B. Davies, *Linear Operators and Their Spectra*, Cambridge University Press (2007).
- D. Bleecker and G. Csordas, *Basic Partial Differential Equations*, International Press, Somerville, Maine (2003).
- Ke Chen, *Matrix Preconditioning Techniques and Applications*, Cambridge University Press (2005).
- S. Puntanen, G. Styan, J. Isotolo, *Matrix Tricks for Linear Models*, Springer (2011)
- B. Thaller, *The Dirac Equation*, Springer (1992)
- F. Chatelin, *Eigenvalues of Matrices*, SIAM (2012)

## COURSES TAUGHT:\*,\*\*

## UNIVERSITY OF COLORADO, DEPARTMENT OF APPLIED MATHEMATICS

			Students
1958 Fall	Intermediate Algebra	A.M. 100	(20)
	College Algebra & Trig.	A.M. 101	(20)
1959 Spring	Intermediate Algebra	A.M. 100	(20)
	College Algebra & Trig.	A.M. 101	(20)
1959 Fall	College Algebra & Trig.	A.M. 101	(20)
	Analytical Geometry & Calculus	A.M. 102	(20)
1960 Spring	Analytical Geometry & Calculus	A.M. 102	(20)
	Calculus	A.M. 231	(20)

## UNIVERSITY OF MINNESOTA, DEPARTMENT OF MATHEMATICS

1966 Fall	College Algebra	Math 15	(60)
	(large lecture)		
	Partial Diff. Eqns. I	Math 173	(30)
1967 Fall	College Algebra	Math 15	(60)
	(large lecture)		
	Calculus	Math 31	(30)
	Partial Diff. Eqns. I	Math 173	(25)
1968 Winter	Calculus	Math 31	(30)
	Calculus (large lecture)	Math 42	(90)
	Partial Diff. Eqns. II	Math 174	(20)
1968 Spring	College Algebra	Math 10-A	(900)
	(course chairman)		
	Ordinary Diff. Eqns.	Math 106	(20)
	Partial Diff. Eqns. III	Math 175	(15)

## ETH LAUSANNE (Ecole Polytechnique Federale de Lausanne)

1971 Fall	Operator Theory	(32 lectures)	(10)
1972 Summer	Open Problems in	(20 lectures)	(5)
	Operator Theory		
1976 Summer	3 <sup>ieme</sup> Cycle Course: Le Spectre Continu	(12 lectures)	(22)

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\*In the capacity of regular faculty member.

\*\*Some of the student numbers are approximate.

## UNIVERSITY OF COLORADO, DEPARTMENT OF MATHEMATICS

			Students
1968 Fall	Intro. to Real Analysis II	Math 532	(15)
	Seminar: Partial Diff. Eqns.	Math 698	(4)
1969 Spring	Advanced Calculus II	Math 432	(25)
	Seminar: Partial Diff. Eqns.	Math 698	(4)
1969 Fall	Intro. to Partial Diff. Eqns.	Math 444	(25)
	Functional Analysis I	Math 635	(20)
1970 Spring	Intro. to Partial Diff. Eqns.	Math 444	(25)
	Functional Analysis II	Math 636	(10)
1970 Fall	Ordinary Diff. Eqns.	Math 443	(20)
	Seminar: Functional Analysis	Math 692	(3)
1971 Spring	Intro. to Partial Diff. Eqns.	Math 444	(25)
	Seminar: Functional Analysis	Math 692	(3)
1972 Fall	Ordinary Differential Eqns.	Math 443	(20)
	Functional Analysis I	Math 635	(30)
1973 Spring	Ordinary Differential Eqns.	Math 443	(27)
	Functional Analysis II	Math 636	(5)
1973 Fall	Intro. to Partial Diff. Eqns.	Math 444	(16)
	Partial Diff. Eqns. I	Math 533	(10)
1974 Spring	Ordinary Diff. Eqns.	Math 443	(31)
	Partial Diff. Eqns. II	Math 534	(5)
1974 Fall	Intro. to P.D.E. I	Math 447/549	(30)
	Intro. to P.D.E. I (2nd section)	Math 447/549	(10)
1975 Spring	Intro. to P.D.E. II	Math 448/550	(14)
	Algebra for Social Sciences & Business	Math 107	(32)
1975 Fall	Intro. to P.D.E. I	Math 447/549	(21)
	Advanced Mathematical Physics III	Math 655 (Physics 605)	(8)
1976 Spring	Intro. to P.D.E. II	Math 448/550	(11)
	Advanced Mathematical Physics IV	Math 656 (Physics 606)	(6)
1976 Fall	Intro. to Linear Algebra	A.Math 236	(41)
	Diff. Eqns. Intro. to P.D.E. I	Math 447/549	(30)
1977 Spring	Intro. to Statistics	Math 281	(45)
	Intro. to P.D.E. II	Math 448/550	(15)
1977 Fall	Intro. to Statistics	Math 281	(25)
	Intro. to P.D.E. I	Math 447/549	(20)
	Seminar: Applied Math.	Math 694	(4)

			Students
1978 Spring	Analytic Geometry & Calculus I (large lecture)	Math 130	(140)
	Intro. to P.D.E. II	Math 448/550	(9)
1979 Fall	Num. Solu. of Initial Value Problems	Math 562 (C.S. 562)	(12)
	Intro. to P.D.E. I	Math 447/549	(41)
1980 Spring	Num. Solu. of Boundary Value Problems	Math 563 (C.S. 563)	(6)
	Intro. to P.D.E. II	Math 448/550	(8)
	Ulam Seminar (with K. Sinha)	Math 698	(3)
1980 Fall	Seminar: Applied Math. Inter. Num. Anal. I	Math 694 Math 465 (C.S. 465)	(5) (35)
1981 Spring	Inter. Num. Anal I Seminar: Applied Math	Math 465 Math 694	(31) (3)
1981 Fall	Num. Solu. of Initial Value Problems	Math 562 (C.S. 562)	(8)
	Advanced Eng. Math.	A.Math 435	(13)
1982 Spring	Int. Num. Anal. II	Math 466 (C.S. 466)	(10)
	Intro. to Linear Algebra & Diff. Eqns.	A.Math 236	(28)
1982 Fall	Intro. to P.D.E. I Intro. to Linear Algebra & Diff. Eqns.	Math 447/549 A.Math 236	(27) (30)
1983 Spring	Intro. to P.D.E. II Intro. to Linear Algebra & Diff. Eqns.	Math 448/550 A.Math 236	(7) (37)
1983 Fall	Calculus for Eng. III (large lecture)	A.Math 235	(136)
	Seminar: Numerical Anal.	Math 695	(7)
1984 Spring	Seminar: Numerical Anal.	Math 695	(6)
1984 Fall	Seminar: Numerical Anal. Intro. to Linear Algebra & Diff. Eqns.	Math 695 A.Math 236	(4) (30)
1985 Spring	Intro. to Linear Algebra & Diff. Eqns.	A.Math 236	(33)
	Intro. to P.D.E. I	Math 447/549	(21)
1985 Fall	Seminar: Applied Math. Intro. to P.D.E. I Ulam Seminar (with R. Temam)	Math 694 Math 447/549 Math 698	(2) (22) (2)



			Students
1986 Spring	Ordinary Diff. Eqns.	Math 443	(35)
	Intro. to P.D.E. II	Math 448/550	(14)
1986 Fall	Intro. to Linear Algebra & Diff. Eqns.	A.Math 236	(30)
1987 Spring	Intro. to Linear Algebra & Diff. Eqns.	A.Math 236	(25)
	(second section)	A.Math 236	(30)
1988 Fall	Partial Diff. Eqns. I	Math 5470	(25)
	Intro to Linear Algebra	Math 3130	(30)
1989 Spring	Partial Diff. Eqns. II	Math 5480	(10)
	Intro. to Partial Diff. Eqns. I	Math 4470	(20)
1989 Fall	Math/Comp. Fluid Dynamics I	Math 8410	(12)
1990 Spring	Math/Comp. Fluid Dynamics II	Math 8420	(8)
	Intro. to Partial Diff. Eqns. I	Math 4470	(22)
1990 Fall	Seminar in Applied Math.	Math 8405	(11)
	Partial Diff. Eqns. I	Math 5470 (A.Math 5470)	(34)
1991 Spring	Seminar in Applied Math	Math 8405	(6)
	Partial Diff. Eqns. II	Math 5480	(7)
1991 Fall	Ordinary Diff. Eqns.	Math 4430	(26)
1992 Spring	Intro. to Partial Diff. Eqns. I	Math 4470	(19)
1992 Fall	Ordinary Diff. Eqns.	Math 5430	(14)
	Compressible Flow Computation (with C. Laney)	Aero 6519	(6)
1993 Spring	Partial Diff. Eqns. II	Math 5480/4480	(6)
	Intro to Linear Algebra	Math 3130	(26)
1993 Fall	Partial Diff. Eqns I	Math 5470 (A.Math 5470)	(17)
1994 Spring	Partial Diff. Eqns. II	Math 5480/4480	(7)
	Calculus III	Math 2400	(28)
1995 Spring	Intro. to Partial Diff. Eqns. I	Math 4470	(12)
	Intro to Linear Algebra	Math 3130	(29)
1995 Fall	Calculus III	Math 2400	(26)
1996 Spring	Intro. to Partial Diff. Eqns. I	Math 4470	(10)
	Partial Diff. Eqns II	Math 5480/4480	(17)
1996 Fall	Analytical Geometry & Calculus I (large lecture)	Math 1300	(109)
	Partial Diff. Eqns. I	Math 5470 (A.Math 5470)	(8)

			Students
1997 Spring	Intro. to Partial Diff. Eqn. I	Math 4470	(10)
1997 Fall	Analytical Geometry & Calculus I (large lecture)	Math 1300	(111)
	Intro to Linear Algebra	Math 3130	(26)
	Partial Diff. Eqns. I	Math 5470 (A.Math 5470)	(8)
1998 Fall	Analytical Geometry & Calculus I (large lecture)	Math 1300	(101)
	Partial Diff. Eqns. I	Math 5470 (A.Math 5470)	(10)
	Ulam Seminar (with J. Bernasconi)	Math 8815	(2)
1999 Spring	Partial Diff. Eqns. II	Math 5480/4480	(15)
1999 Fall	Partial Diff. Eqns. I	Math 5470 (A.Math 5470)	(13)
2000 Spring	Partial Diff. Eqns. II	Math 5480/4480	(6)
	Intro to Linear Algebra	Math 3130	(28)
	Complex Variables	Math 4450	(20)
2000 Fall	Intro to Partial Diff. Eqns. I	Math 4470	(20)
	Partial Diff. Eqns. I	Math 5470 (A.Math 5470)	(7)
2002 Fall	Intro to Partial Diff Eqns. I	Math 4470	(25)
	Intro to Linear Algebra	Math 3130	(20)
2003 Spring	Intro to Complex Variables	Math 4450	(26)
2003 Fall	Intro to Partial Diff. Eqns	Math 4470/5470	(24)
2004 Spring	Ordinary Differential Eqns	Math 4430	(27)
	Linear Algebra	Math 5150	(10)
2004 Fall	Intro to Partial Diff. Eqns	Math 4470/5470	(25)
	Intro to Linear Algebra	Math 3130	(28)
2005 Spring	Linear Algebra	Math 5150	(20)
2005 Fall	Intro to Partial Diff. Eqns	Math 4470/5470	(21)
	Ordinary Differential Eqns	Math 4430	(20)
2006 Spring	Linear Algebra	Math 5150	(18)
2006 Fall	Intro to Partial Diff. Eqns	Math 4470/5470	(28)
	Math for the Environment	Math 2380	(27)
2007 Spring	Linear Algebra	Math 5150	(12)
2007 Fall	Intro to Partial Diff. Eqns	Math 4470/5470	(21)
	Ordinary Differential Eqns	Math 4430	(23)
2009 Spring	Linear Algebra	Math 5150	(22)
2009 Fall	Intro to Partial Diff. Eqns	Math 4470	(15)
	Intro to Partial Diff. Eqns	Math 5470	(8)
	Intro to Linear Algebra	Math 3130	(25)

			Students
2010 Spring	Functions of a Complex Variable	Math 6350	(12)
2010 Fall	Intro to Partial Diff. Eqns	Math 4470	(20)
	Intro to Partial Diff. Eqns	Math 5470	(6)
2011 Spring	Intro to Partial Diff. Eqns.	Math 4470	(17)
	Intro to Partial Diff. Eqns.	Math 5470	(8)
	Linear Algebra	Math 5150	(12)
2011 Fall	Intro to Partial Diff. Eqns.	Math 4470	(20)
	Intro to Partial Diff. Eqns.	Math 5470	(6)
2012 Spring	Intro to Linear Algebra	Math 3130	(55)
	Harmonic Analysis	Math 8370	(9)
2012 Fall	Ordinary Differential Eqns.	Math 4430	(26)
	Intro to Partial Diff. Eqns.	Math 4470	(20)
	Intro. to Partial Diff. Eqns.	Math 5470	(5)
2013 Spring	Intro to Partial Diff. Eqns.	Math 4470	(20)
	Intro to Partial Diff. Eqns.	Math 5470	(6)
2013 Fall	Intro to Linear Algebra	Math 3130	(40)
2014 Fall	Intro to Linear Algebra	Math 3130	(38)
	Intro to Partial Diff. Eqns.	Math 4470	(20)
	Intro to Partial Diff. Eqns.	Math 5470	(6)
2016 Spring (3 weeks)	Intro to Partial Diff. Eqns.	Math 4470	(20)
	Intro to Partial Diff. Eqns.	Math 5470	(7)