

Proceedings of Symposia in PURE MATHEMATICS



VOLUME XXIII

**PROCEEDINGS OF SYMPOSIA
IN PURE MATHEMATICS
Volume XXIII**

**PARTIAL DIFFERENTIAL
EQUATIONS**

**AMERICAN MATHEMATICAL SOCIETY
PROVIDENCE, RHODE ISLAND
1973**

PROCEEDINGS OF THE SYMPOSIUM IN PURE MATHEMATICS
OF THE AMERICAN MATHEMATICAL SOCIETY

HELD AT THE UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA
AUGUST 9-27, 1971

Edited by
D. C. SPENCER

*Prepared by the American Mathematical Society
under National Science Foundation Grant GP-28200*

Library of Congress Cataloging in Publication Data

Symposium in Pure Mathematics, University of
California at Berkeley, 1971.
Partial differential equations.

(Proceedings of symposia in pure mathematics, v. 23)
"An outgrowth of lectures delivered at the eighteenth
Summer Research Institute of the American Mathematical
Society ... held ... from August 9 to August 27, 1971."
Includes bibliographical references.
1. Differential equations, Partial--Congresses.
I. Spencer, Donald Clayton, 1912- ed.
II. American Mathematical Society. III. Title.
IV. Series.
QA374.S93 1971 515'.353 72-4071
ISBN 0-8218-1423-0

AMS (MOS) subject classifications (1970). Primary 35-XX

Copyright © 1973 by the American Mathematical Society

Reprinted without corrections, 1977
Printed in the United States of America

*All rights reserved except those granted to the United States Government.
This book may not be reproduced in any form without the permission of the publishers.*

CONTENTS

Preface	vii
Lecture Series		
Existence and regularity of hypersurfaces of R^n with prescribed mean curvature	1
BY MARIO MIRANDA		
Recent applications of index theory for elliptic operators	11
BY I. M. SINGER		
On the existence and regularity of solutions of linear partial differential equations	33
BY F. TREVES		
Introductory Expository Lecture		
Pseudo-differential operators and hypoellipticity	61
BY J. J. KOHN		
Seminar on Linear Problems		
Nodal and critical sets for eigenfunctions of elliptic operators	71
BY J. H. ALBERT		
Analyticity for degenerate elliptic equations and applications	79
BY M. S. BAOUENDI AND C. GOULAOUIC		
Prolongement et existence des solutions des systèmes hyperboliques non-stricts à coefficients analytiques	85
BY JEAN-MICHEL BONY ET PIERRE SCHAPIRA		
Growth properties of solutions of certain “canonical” hyperbolic equations with subharmonic initial data	97
BY ROBERT CARROLL AND HOWARD SILVER		
Tangential Cauchy-Riemann complexes on spheres	105
BY G. B. FOLLAND		
Semibounded boundary problems for elliptic operators	113
BY GERD GRUBB		
Complexes of differential operators	125
BY VICTOR GUILLEMIN		

Removable singularities and structure theorems for positive currents	129
BY REESE HARVEY	
The Cauchy problem for $\bar{\partial}$	135
BY C. DENSON HILL	
On hypoellipticity of second order equations	145
BY O. A. OLEINIK	
On the exterior problem for the reduced wave equation	153
BY RALPH S. PHILLIPS	
General theory of hyperbolic mixed problems	161
BY JEFFREY RAUCH	
Analytic torsion	167
BY D. B. RAY AND I. M. SINGER	
An application of von Neumann algebras to finite difference equations	183
BY DAVID G. SCHAEFFER	
Evolution equations not of classical type and hyperdifferential operators	195
BY STANLY STEINBERG	
The change in solution due to change in domain	199
BY GILBERT STRANG AND ALAN E. BERGER	
Variations of Korn's and Sobolev's inequalities	207
BY MONTY J. STRAUSS	
Probability theory and the strong maximum principle	215
BY DANIEL W. STROOCK AND S. R. S. VARADHAN	
Coerciveness for the Neumann problem	221
BY W. J. SWEENEY	
A Fredholm theory for elliptic partial differential operators in R^n	225
BY HOMER F. WALKER	

Seminar on Nonlinear Problems

An introduction to regularity theory for parametric elliptic variational problems	231
BY W. K. ALLARD AND F. J. ALMGREN, JR.	
Two minimax problems in the calculus of variations	261
BY MELVYN S. BERGER	
Existence theory for boundary value problems for quasilinear elliptic systems with strongly nonlinear lower order terms	269
BY FELIX E. BROWDER	
Existence theorems for problems of optimization with partial differential equations	287
BY LAMBERTO CESARI	
Topological methods in the theory of shock waves	293
BY CHARLES C. CONLEY AND JOEL A. SMOLLER	

TABLE OF CONTENTS

v

Generalizations of the Korteweg-de Vries equation BY THEODORE E. DUSHANE	303
General relativity, partial differential equations, and dynamical systems BY ARTHUR E. FISCHER AND JERROLD E. MARSDEN	309
Elliptic equations on minimal surfaces BY ENRICO GIUSTI	329
Justification of matched asymptotic expansion solutions for some singular perturbation problems BY FRANK HOPPENSTEADT	337
Deformations leaving a hypersurface fixed BY HOWARD JACOBOWITZ	343
The regularity of the solution to a certain variational inequality BY DAVID KINDERLEHRER	353
Asymptotics of a nonlinear relativistic wave equation BY CATHLEEN S. MORAWETZ AND WALTER A. STRAUSS	365
Propagation of zeroes of solutions of P.D.E.'s along leaves of foliations.. BY E. C. ZACHMANOGLOU	369

Seminar on Geometry

Affine connections with zero torsion .. BY BOHUMIL CENKL	375
On the Spencer cohomology of a Lie equation BY HUBERT GOLDSCHMIDT	379
Curvature functions for 2-manifolds .. BY JERRY L. KAZDAN AND F. W. WARNER	387

Seminar on Mathematical Physics

Scattering with long range potentials .. BY P. ALSHOLM AND TOSIO KATO	393
What is renormalization? .. BY JAMES GLIMM AND ARTHUR JAFFE	401
Quantum fields and Markoff fields .. BY EDWARD NELSON	413
On the steady fall of a body in a Navier-Stokes fluid .. BY H. F. WEINBERGER	421
Relativistic wave equations as singular hyperbolic systems .. BY A. S. WIGHTMAN	441

Seminar on Singular Integral Operators

<i>L^p-L^q</i> -estimates for singular integral operators arising from hyperbolic equations	477
BY WALTER LITTMAN	
One-sided conditions for functions harmonic in the unit disc	483
BY VICTOR L. SHAPIRO	
Author Index	491
Subject Index	497

PREFACE

The papers in these Proceedings are an outgrowth of lectures delivered at the eighteenth Summer Research Institute of the American Mathematical Society. The topic of the institute was partial differential equations, and it was held at the University of California at Berkeley from August 9 to August 27, 1971. The institute was financed by the National Science Foundation.

Notes of lectures were distributed during the conference (and remaining notes shortly afterward) to the participants, and many of the papers appearing in this volume are revised versions of the informal notes. Although some of the papers are expositions of known material, many contain new results. The papers are arranged under the headings of the five seminars of the conference: linear problems, nonlinear problems, geometry, mathematical physics, and singular integral operators.

The organizing committee for the institute consisted of: Alberto P. Calderón, Lars Hörmander, Charles B. Morrey, Jr., Louis Nirenberg (Chairman), James B. Serrin, Isadore M. Singer and Donald C. Spencer.

The editor would like to thank the many persons who cooperated to make the institute and this volume possible. Of special direct help were Lillian R. Casey, Beth Clarke, Hope Daly (conference secretary), Carole Kohanski and Margaret Reynolds.

D. C. SPENCER

AUTHOR INDEX

Italic numbers refer to pages on which a complete reference to a work by the author is given.

Roman numbers refer to pages on which a reference is made to a work of the author. For example, under Shiffman would be the page on which a statement like the following occurs: "The following corollary generalizes a result of Shiffman...."

Boldface numbers indicate the first page of the articles in this volume.

- Abraham, R., 310, 325, 326
Agmon, S., 121, 122, 122, 304, 307
Albert, J. H., 71, 78
Allard, W. K., 4, 9, **231**, 260
Almgren, F. J., Jr., 3, 8, **231**, 260
Alsholm, P., **393**
Amrein, W. O., 394, 399
Andreotti, A., 136, 139, 142
Arena, O., 481
Arnowitt, R., 310, 321, 325
Atiyah, M. F., 19, 20, 23, 29, 30
Bauendi, M. S., 69, **79**, 83, 84
Baum, P. F., 30
Berger, Alan E., **199**
Berger, Melvyn S., **261**, 265, 267,
 389, 391
Bergman, S., 199, 205
Bers, L., 230, 362, 481
Bishop, R. L., 371, 374
Bombieri, E., 3, 8, 9, 132, 133, 260,
 329, 336
Bony, Jean-Michel, 85, 85, 95, 219,
 220, 370, 372, 373
Bott, R., 30
Bramble, J., 204, 205
Brenner, H., 435, 437, 439
Breuer, M., 191, 193
Brézis, H. R., 271, 285, 285, 355, 363
Browder, Felix E., **269**, 269, 271,
 274, 280, 285, 285, 286
Buslaev, V. S., 394, 399
Calderón, A. P., 115, **122**
Capri, A., 477
Carroll, Robert W., **97**, 104
Cenkl, Bohumil, **375**
Cesari, Lamberto, **287**
Chavel, I., 264, 267
Cheeger, J., 30
Chern, S. S., 264, 267
Chevalley, C., 371, 373
Choquet-Bruhat, Y., 309, 312, 326
Coburn, L., 185, 193
Conley, Charles C., **293**, 294, 295,
 302
Conner, P. E., **181**
Courant, R., 78, 203, 205, 315, 316,
 326, 363, 391
De Giorgi, E., 3, 8, 9, 260, 329, 331,
 333, 336
Derridj, M., 146, **151**
Deser, S., 310, 321, 325
DeWitt, B., 310, 321, 322, 326
Dimock, J., **411**

- Dionne, P., 309, 312, 326
 Dixmier, J., 185, 193
 Dollard, J. D., 393, 399
 Douglas, R., 185, 193
 Draper, R., 132, 133
 Dubinskii, Ju. A., 286
 Du Chateau, P., 197, 198
 Duffin, R. J., 464, 477
 Dupont, J. L., 19, 30
 Dushane, Theodore E., 303
 Duvaut, C., 207, 214
 Eardley, D., 323, 326
 Easton, R. W., 302
 Ebin, D. G., 310, 325, 326
 Eckhaus, W., 339, 341
 Eckman, J.-P., 411
 Egorov, Yu. V., 47, 60
 Ehrenpreis, L., 104
 Einstein, A., 311, 326
 Eisenhart, L., 351
 Emmer, M., 5, 9
 Fabrey, J., 411
 Federbush, P., 476, 477
 Federer, H., 4, 9, 131, 132, 133, 260,
 330, 331, 336
 Fedii, V. S., 151
 Fichera, G., 220
 Fierz, M., 465, 476, 477
 de Figueiredo, D. G., 208, 214
 Finn, R., 422, 439
 Fischer, Arthur E., 309, 310, 312,
 313, 315, 316, 322, 326
 Fitzpatrick, P. M., 285, 286
 Fleming, W. H., 8, 330, 333, 336
 Folland, G. B., 105, 106, 112
 Fourès-Bruhat, F., 311, 326
 Foy, R., 295, 302
 Frankl, F., 315, 326
 Friedman, A., 208, 214
 Friedrichs, K. O., 207, 214, 230,
 315, 326
 Fujiwara, D., 122, 122
 Fusaro, B. A., 104
 Gagliardo, E., 8
 Gårding, L., 476
 Gardner, C. S., 303, 307
 Gel'fand, I. M., 197, 481
 Giaquinta, M., 9, 355, 363
 Gilkey, P., 15, 30
 Giusti, Enrico, 3, 8, 260, 329, 329,
 333, 336
 Glass, A., 474, 477
 Glimm, James, 401, 411, 419, 420
 Gluck, H., 389, 391
 Gohberg, I. C., 230
 Goldberg, S. I., 371, 374
 Goldschmidt, Hubert, 379, 385
 Goulaouic, C., 69, 79, 83, 84
 Grauert, H., 142
 Green, G., 405, 411
 Grubb, Gerd, 113, 114, 122, 122
 Grušin, V. V., 69
 Guillemin, Victor W., 125, 127, 223,
 223, 379, 382, 385
 Haefliger, André, 375, 377
 Happel, J., 439
 Harish-Chandra, 461, 477
 Harvey, Reese, 129, 130, 132, 133
 Helgason, S., 104
 Hepp, K., 411
 Hermann, Robert 371, 373
 Hersh, R., 164, 166
 Hess, P., 285, 286
 Hilbert, D., 78, 205, 315, 316, 326,
 363, 391
 Hill, C. Denson, 135, 136, 142, 219,
 220
 Hirzebruch, F., 23, 25, 30
 Hoppensteadt, Frank, 337, 341
 Hörmander, L., 11, 30, 36, 43, 60,
 61, 68, 69, 69, 84, 86, 95, 115, 122,
 127, 127, 139, 143, 145, 150, 151,
 198, 372, 374, 477

- Hsiang, W. C., 25, 30
Iino, R., 303, 307
Ince, E. L., 78
Itô, K., 220
Jacobowitz, Howard, 343, 351
Jaffe, Arthur, 365, 401, 411, 413,
 419, 420
Jenkins, H., 9
John, F., 230, 362, 372, 374, 481
Jost, Res, 411, 418, 420
Kametaka, Y., 307
Kato, Tosio, 230, 262, 267, 393, 399
Kawai, T., 85, 95
Kazdan, Jerry L., 267, 387, 391, 392
Kearsley, E. A., 439
Keller, J. B., 340, 341, 439
Kemmer, N., 464, 477
Kinderlehrer, David, 353, 363
King, J., 132, 133
Kiselman, C.-O., 85, 95
Kogelman, S., 340, 341
Kohn, J. J., 61, 61, 69, 105, 106, 111,
 112, 112, 139, 143, 151, 230, 230
Kosniowski, C., 30
Kotake, T., 84
Koutroufiotis, D., 389, 391
Krein, M. G., 230
Kreiss, H. O., 164, 166
Kristensen, P., 477
Kruskal, M. D., 303, 307
Kulikovskii, A. G., 295, 299, 302
Kuman-Go, H., 371, 374
Kumpera, A., 385
Kuo, T., 78
Kupradse, W. D., 153, 160
Kwoh, D., 457, 477
Ladyženskaja, O. A., 422, 424, 428,
 429, 431, 439
Lanczos, C., 311, 326
Landau, L. D., 302
Landesman, E. M., 391, 391
Lawson, B., 132, 133
Lax, P. D., 48, 60, 160, 227, 230,
 302, 303, 307, 315, 326
Lazer, A. C., 391, 391
Leis, R., 153, 160
Lelong, P., 131, 133
Leray, J., 95, 271, 286, 309, 326,
 421, 422, 439, 481
Levin, B. Ja., 193
Lewy, H., 9, 105, 106, 112, 140, 143,
 354, 355, 363
Liang, E., 323, 326
Lichnerowicz, A., 24, 30, 309, 326
Lifschitz, E. M., 302
Lions, J. L., 84, 115, 122, 123, 194,
 207, 214, 271, 286
Littman, Walter, 479, 481
Ljusternik, L. A., 340, 341
Ludwig, D. A., 481
Lusztig, G., 24, 25, 30
Magenes, E., 84, 115, 122, 123, 194
Malgrange, B., 125, 127, 150, 379,
 384, 385
Marsden, Jerrold E., 309, 310, 312,
 313, 315, 316, 325, 326
Martin, Ph. A., 394, 399
Massari, U., 4, 8
Matsuda, M., 371, 374
Matsuura, S., 95
Matveev, V. B., 394, 399
Mautner, F. I., 104
Mazzone, Silvia, 362
Mejlbo, L., 477
Milgram, A. N., 181
Miller, M., 197, 198
Miller, W., Jr., 104
Milnor, J. W., 24, 30, 181
Minakshisundaram, S., 181
Minkowski, P., 477
Minty, G. J., 286

- Miranda, Mario**, 1, 3, 8, 9, 329, 332, 336, 355, 363
- Misner, C. W.**, 310, 321, 325
- Misra, B.**, 394, 399
- Miura, R. M.**, 303, 307
- Molyneux, J. E.**, 439
- Morawetz, Cathleen S.**, 363
- Morrey, C. B., Jr.**, 84, 286
- Moser, J.**, 332, 333, 336, 389, 390, 391, 392
- Mukasa, T.**, 303, 307
- Müller, C.**, 153, 160
- Nagano, T.**, 370, 371, 373
- Nagumo, T.**, 151
- Narasimhan, N. S.**, 84
- Nečas, J.**, 205, 285, 286
- Nelson, Edward**, 413, 420
- Nirenberg, L.**, 60, 63, 69, 84, 106, 111, 112, 139, 143, 220, 230, 230, 391, 392
- Novikov, S. P.**, 25, 30
- Ohya, Y.**, 95
- Oleiník, O. A.**, 62, 69, 145, 151, 306, 307
- Osserman, R.**, 392
- Ovsjannikov, L. V.**, 197
- Palais, R. S.**, 30
- Patodi, V. K.**, 15, 30, 31
- Pauli, W.**, 465, 476, 477
- Pepe, L.**, 9, 355, 363
- Petiau, G.**, 464, 477
- Petrovskii, I.**, 315, 326
- Petryshyn, W. V.**, 285, 286
- Phillips, Ralph S.**, 153, 160, 227, 230
- Pleijel, A.**, 181
- Pohožaev, S. I.**, 285, 286
- Polking, J.**, 133
- Poulsen, E. T.**, 477
- Radkevič, E. V.**, 61, 62, 69, 145, 151
- Radó, T.**, 357, 363
- Ralston, J.**, 164, 166
- Rauch, Jeffrey**, 161, 164, 166
- Ray, D. B.**, 31, 167, 167, 181
- Redheffer, Ray**, 219, 220
- Reeb, Georges**, 377
- Reifenberg, E. R.**, 331, 336
- Rellich, F.**, 78
- Remmert, R.**, 129, 133
- de Rham, G.**, 181
- Rosen, L.**, 411, 420
- Rosenbloom, P. C.**, 181
- Rossi, H.**, 105, 106, 112, 143
- Royden, H. L.**, 490
- Rubenfeld, L. A.**, 439
- Sachs, R.**, 323, 326
- Sakamoto, R.**, 166
- Saks, S.**, 490
- Santi, E.**, 9
- Sapiro, Z. Ja.**, 481
- Sato, M.**, 85, 91, 92, 95
- Schaeffer, David, G.**, 183, 185, 193, 194
- Schapira, Pierre**, 85, 85, 95
- Schauder, J.**, 315, 326, 421, 439
- Schechter, M.**, 230, 362, 481
- Schiffer, M.**, 199, 205
- Schrader, R.**, 411
- Schroer, B.**, 477
- Schwartz, L.**, 145, 151
- Seeley, R. T.**, 31, 78, 115, 123
- Segal, G. B.**, 30
- Segal, I. E.**, 476
- Seiler, R.**, 477
- Serrin, J.**, 9
- Shapiro, A.**, 30
- Shapiro, Victor L.**, 483, 490
- Shenk, N.**, 153, 160, 160
- Shiffman, B.**, 129, 131, 132, 133, 133
- Shimakura, N.**, 122, 122
- Shirota, T.**, 165, 166
- Silov, G. E.**, 197
- Silver, Howard**, 97

- Simons, J., 3, 8, 333, 336
Simons, S., 132, 133
Singer, I. M., 11, 30, 31, 167, 167,
 181, 185, 193
Sjöberg, A., 307
Smoller, Joel A., 293, 294, 295, 302
Sobolev, S. S., 316, 319, 326, 327
Speer, E. R., 459, 477
Spencer, D. C., 223, 379, 385
Stampacchia, G., 9, 354, 355, 363
Stein, E. M., 480, 481
Stein K., 129, 133
Steinberg, Stanly, 160, 195, 197, 198
Sternberg, S., 127, 223, 379, 382,
 385
Stoker, J. J., 392
Strang, Gilbert, 199, 204, 205
Strauss, Monty J., 207
Strauss, Walter A., 285, 285, 286,
 365
Streater, R., 411, 417, 420
Strichartz, R. S., 479, 481
Stroock, Daniel W., 215, 220
Sweeney, W. J., 106, 112, 221, 222,
 223
Swieca, J. A., 477
Symanzik, K., 413, 420
- Temam, R., 304, 307
Thie, P., 131, 133
Thoe, D., 153, 160, 160
Thomas, E., 31
Tomi, F., 355, 363
- Trenogin, V. A., 340, 341
Treves, F., 33, 60, 69, 69, 150, 196,
 197, 198
Triscari, D., 8
Trudinger, N. S., 334, 336
Tsutsumi, M., 303, 304, 307
- Vainberg, M. M., 267
Varadhan, S. R. S., 215, 220
Velo, G., 454, 476
Vesentini, E., 139, 142
Vilenkin, N. Ja., 104
Višik, M. I., 115, 123, 286, 340, 341
- Walker, Homer F., 225, 230
Wallach, N., 392
Warner, F. W., 267, 387, 391, 392
Weinberger, H. F., 421, 439
Weinstein, A., 97, 104
Werner, P., 153, 160
Weyl, H., 153, 160
Wheeler, J. A., 310, 321, 327
Wightman, A. S., 365, 401, 411, 413,
 417, 418, 420, 441, 476, 477
Wille, F., 285, 286
Wittich, H., 390, 392
- Yosida, K., 327
- Zachmanoglou, E. C., 151, 369, 370,
 373, 374
Zerner, M., 86, 95
Zlamal, M., 204, 205
Zwanziger, D., 454, 476
Zygmund, A., 481, 490

Subject Index

- abstract existence theory, 270, 315
- abstract parabolic problem, 340
- additive functional, 418
- additive Riemann-Hilbert problem, 138
- affine connection, 375
- amplitude function, 53, 55, 56
- analytic function, 80, 148
- analytic-hypoelliptic, 34, 38, 44, 46, 83
- analytic torsion, 172
 - as a function of cohomology, 177
- analytic vector, 196
- analyticity, 79
- annihilation operator, 446
- approximate m -dimensional tangent plane, 236
- a priori estimate, 304, 315
 - for the perturbed problem, 305, 319
- asymptotic behavior, 310, 313, 316, 365
- asymptotic hypersurface, 310, 313, 316, 345
- augmented osculating space, 345
- axial symmetry, 439
- Banach spaces, new classes of mappings in, 269
- basic inequality of regularity theory, 239, 316
- basic regularity property, 236, 315
- Beltrami equation, 355
- Bernstein's theorem, 253, 333
- bicharacteristic curve, 42
- bicharacteristic strip, 41
 - null, 41, 43, 44
- Borsuk-Ulam type of existence theorems, 285
- boundary behavior of minimal hypersurface in R^n , 5
- boundary cohomology, 137, 140
- boundary conditions,
 - general, 114
 - normal pseudo-differential, 118
- boundary control, 287
- boundary layer, 202
- boundary value problem, existence theory for solutions of, 269
- bracket, 370
- bump lemma, 141
- calculus of variations, 261, 390
- canonical anticommutation relations, 447
- canonical commutation relations, 447
- canonical infinite sequence of hyperbolic equations, 97
- canonical recursion relation, 102
- canonical resolvent sequence, 99, 101, 102

- capacity, 425
- CAR, 447
- Cauchy data, 309
- Cauchy-Goursat problem, 196
- Cauchy-Kovalevska theorem, 150, 196
- Cauchy problem, 91, 92, 135, 142, 311, 476
- CCR, 447
- center of stress, 437
- characteristic, 126, 309, 311
- characteristic cone, 369, 371, 372
- characteristic variety, 126
- charge conjugation, 459
- classifying space $B\Delta_q$, 375
- closure theorems, 288
 - lower, 288
- coercive estimate, 221
- cohomology, 136
 - analytic torsion as a function of, 177
 - boundary, 137, 140
- commutator, 370
- compatibility conditions, 135, 165
- compatible, 234
- complete minimal graph, 333
- complete Riemannian metric, 310, 388
- complex manifold, 16, 22, 135, 261
- complex of operators, 125
- complex subvariety, 129
- condition (S)₊ or (S), 274
- configuration space, 310, 322, 324
- conformal equivalence, 356, 387
- conformal metric, 387
- conic, 48
- conservation laws, 293, 303, 325
- constraint, 322
- continuable initial condition, 164, 309, 312, 315, 317, 319
- contraction mapping principle, 315
- contraction semigroup, 114, 122, 316
- controls,
 - boundary, 287
 - distributed, 287
- convex function, 488
- convexity theorem, 97, 102
- cotangent bundle, 41
- Coulomb potential, 393
- creation operator, 446
- critical point, 71
 - nondegenerate, 71
 - of an eigenfunction, 71
- critical point theory, 264
 - of Ljusternik-Schnirelman, 264
- cross product, 322
- curvature form, 390
- curvature function, 387
- $\bar{\partial}_b$ complex, 105
- $\bar{\partial}$ -Neumann problem, 106
- Darboux equation, 97, 98, 102, 103
- degenerate dynamical system, 310
- degenerate elliptic equation, 79
 - second order, 370
- degenerate Lagrangian, 324
- degree of the mapping, 432, 433, 434
- DeWitt metric, 322
- diffeomorphism, 321
- differential equation,
 - formally integrable, 380
 - linear, 319
 - nonlinear hyperbolic, 365
 - partial, 309, 365
 - semilinear elliptic, 264
 - Spencer cohomology group of, 381
- differential form, 136
- differential ideal, 136
- differential operator,
 - second-order, selfadjoint, C^∞
 - elliptic on a compact manifold, 71, 145, 147
 - $2m$ -order elliptic, 113
- Dirac equation, 312, 442

- Dirichlet form, generalized, 270
 Dirichlet integral, 200, 354
 Dirichlet problem, 199
 for the minimal hypersurfaces equation, 5
 Dirichlet's principle, 426
 distributed control, 287
 divergence, 322, 410
 Dolbeault complex, 136
 domain of holomorphy, 138, 140
 dot product, 322
 drag, 422, 428
 dynamical formulation, 321
 dynamical system, degenerate, 310
 eigenfunction, generic, 71
 eigenvalue, 81
 simple, 72
 Einstein equations, 309
 existence for, 312
 uniqueness for, 319
 elliptic, 34, 48, 50, 51, 126
 strongly, 114
 elliptic boundary value problem, 121, 153, 162, 163, 183
 elliptic equation, 370
 degenerate, 79
 second order, 370
 nonexistence, 391
 nonlinear, 391
 elliptic integrand, 232
 elliptic operator, 11, 225, 372
 null-space of, 225
 dimension of, 225
 transversal, 11, 12, 106
 ellipticity bound, 233
 energy type estimate, 315
 envelope of holomorphy, 137
 EPD theory, 97, 100
 Euclidean field, 416
 Euler angle, 100, 101
 Euler-Poisson-Darboux equation, 97
 evolution equation, 195, 322
 excess, 236
 existence theorems of the Borsuk-Ulam type, 285
 existence theory for solutions of boundary value problem, 269
 extension of the strong maximum principle for the solutions of minimal surface equations, 6
 exterior problem for the reduced wave equation, 153
 exterior trace, 3
 external field, 444
 external field problem, 469
 fall,
 steady, 421
 isolated direction of, 433, 435, 436
 families index, 11, 14
 finite difference approximation, 183
 finite element method, 199, 202
 finite speed of propagation, 164, 165
 finiteness theorems, 141
 first boundary value problem, 219
 first order equation, 309, 370
 first order operator, 373
 first variation distribution, 255
 first variation of area, 254
 fixed point formula, 11
 $\Phi_{\alpha\kappa}$ space, 445
 foliation, 370, 371, 373, 375
 leaf of, 370, 371, 372
 forcing function, 72, 309, 323
 formally exact, 125
 formally integrable differential equation, 380
 formally transitive Lie equation, 381
 Fourier transform, 102, 103
 partial, 99
 fourth order perturbation, 304
 Fredholm alternative, nonlinear, 285
 Fredholm index, 225
 Fredholm operator, 225
 functional, 287
 fundamental kernel, 38, 49

- Galerkin approximant, 281
- Galerkin method, 285
- Gårding's inequality, 114
- Gauss-Bonnet theorem, 387
- Gauss mapping of a minimal surface, 354
- Gaussian curvature, 348, 354, 387
- Gaussian stochastic process, 414
- general boundary conditions, 114
- generalized degree theory, 285
 - for A -proper mappings, 285
- generalized Dirichlet form, 270
- generic, 71
 - eigenfunction, 71
- geodesic polar coordinates, 98, 100, 101
- geometric measure theory, 231
- Gevrey classes, 80
- Gevrey function, 196
- G -index, 12
- global existence for the perturbed problem, 305
- global hypoelliptic, 145
- growth theorem, 97, 102
- Hamiltonian, 41, 402, 417
- harmonic coordinates, 309, 311, 319
- harmonic function, 483
- Harnack inequality, 329
- heat equation, 15
- helicity spectrum, 443
- Hermitian metric, 261
- Hessian, 322
- Holmgren's theorem, 91, 166, 196
- Holmgren's uniqueness theorem, 372
- holomorphic semigroup, 122
- holomorphy,
 - domain of, 138, 140
 - envelope of, 137
- homotopy index, 296
- Huyghens' Principle, 166
- hyperbolic, 34, 48
 - hyperbolic equation, 309, 310
 - canonical infinite sequence of, 97
 - L^p , L^q -estimates for, 479
 - singular integral operator arising from, 479
 - hyperbolic mixed problem, 161
 - hyperbolic system, 365
 - singular, 441, 454, 475
 - strictly, 162, 309
 - symmetric, 161, 309, 315
 - hypercontractivity, 415
 - hyperdifferential operator, 195, 196
 - hypersurface,
 - asymptotic, 310, 313, 316, 345
 - minimal, 331, 353
 - of R^n with prescribed mean curvature, 1
 - hypoelliptic, 34, 37, 38, 41, 43, 44, 46, 47, 48, 61, 145
 - analytic-, 34, 38, 44, 46
 - global, 145
 - index,
 - families, 11, 14
 - G -, 12
 - homotopy, 296
 - mod 2, 11
 - ordinary, 11
 - transversal, 11, 12
 - index theory, 11
 - initial value,
 - resolvent, 99, 101
 - subharmonic, 97
 - initial value problem, 135, 303, 311, 312, 315
 - periodic, 303
 - integral current, 251
 - modulo ν , 251
 - integral curve, 371
 - integral manifold, 370
 - maximal, 370, 371
 - integral varifold, 251

- integrand, 232
 - elliptic, 232
 - m -dimensional area, 232
 - nonparametric, 242
 - with constant coefficients, 232
- integro-differential sesquilinear form, 121
- interior trace, 3
- interpolation, 204, 397
- interpolation space, 81
- intertwining properties, 394
- isolated direction of fall, 433, 435, 436
- isolating block, 296
- isometric deformation, 344
- Kelvin transformation, 263
- Klein-Gordon divisor, 461
- Klein-Gordon equation, 262
- Klein paradox, 445
- Korn's inequality, 207
- Korteweg-de Vries equation, generalizations of, 303
- L^p -, L^q -estimates for hyperbolic equations, 479
- L_p regularity theory, 266
- Lagrangian, 323, 324
 - degenerate, 324
- Lagrangian system, 310, 323
- Laplace-Beltrami operator, 264
- Laplacian, 388
- leaf of the foliation, 370, 371, 372
- Legendre's operator, 79
- Leray-Schauder theorem, 434
- Leray-Schauder theory, 432
- Levi convexity, 136
- Levi form, 127, 138, 140, 142
- Lewy, H.,
 - example of, 140
 - problem, 137,
 - obstruction to the, 140
- Lichtenstein Theorem, 355
- Lie algebra, 370
 - transitive, 382
- Lie derivative, 322, 324, 325
- Lie equation, 381
 - formally transitive, 381
 - nonlinear Spencer cohomology group of, 383
- linear differential equation, 319, 380
- linearized problem, 305
- Lipschitz continuous, 353
- Ljusternik-Schnirelman, critical point theory of, 264
- local existence for the perturbed initial value problem, 304
- locally coercive C^1 vector field, 353
- locally solvable, 34, 37, 41, 43, 44, 46, 47, 140
- long range potential, 393
- lower closure theorems, 288
- lower semicontinuity, 288
- mappings in Banach spaces, new classes of, 269
- marginally hyperbolic, 164, 165
- Markoff field, 416
- Markoff property, 416
- mass gap, 406
- mass renormalization, 405
- mass spectrum, 443
- matched asymptotic expansion, 337
- maximal integral manifold, 370, 371
- maximum principle, 354, 356, 360, 426
- m -dimensional area integrand, 232
- m -dimensional Hausdorff measure, 232
- mean curvature, 255
 - boundary, 255
- mean value, 98, 102
- minimal hypersurface, 331, 353
- minimal surface, 353
 - Gauss mapping of, 354

- minimax problem, 261
- Minkowski problem, 389
- mixed problem, hyperbolic, 161
- mod 2 index, 11
- modified wave operator, 393
- Morse function, 71
- m -rectifiable, 233
- multiplicative functional, 419
- Navier-Stokes equation, 421
- Navier-Stokes fluid, 421, 422, 430
- Newton's method, 344
- nodal set, 71
- nondegenerate critical point, 71
- nonlinear eigenvalue problem, 285
- nonlinear elliptic equation, 391
 - nonexistence theorems, 391
- nonlinear Fredholm alternative, 285
- nonlinear hyperbolic differential equation, 365
- nonlinear mapping, 270
- nonlinear Spencer cohomology group of a Lie equation, 383
- nonlinear wave equation, 404
 - relativistic, 365
- nonnegativity, 117
- nonparametric integrand, 242
- nonskew body, 437
- normal pseudo-differential boundary conditions, 118
- Novikov higher signature, 24
- null bicharacteristic strip, 41, 43, 44
- obstacle, 5
- obstruction to the H. Lewy problem, 140
- one-sided condition, 483
- optimization, problems of, 287
- ordinary index, 11
- Palais-Smale "condition C", 261
- parabolic, 34
- parabolic problem,
 - abstract, 340
 - quasilinear, 340
- parametrix, 50, 52, 55
- partial differential equation, 309, 365
- partial Fourier transform, 99
- periodic initial value problem, 303
- perturbed initial value problem,
 - local existence for, 304
- perturbed problem, 153, 304
 - a priori estimate for, 305
 - global existence for, 305
- phase function, 53, 55
- piecewise linear function, 203
- piecewise polynomial function, 202
- piecewise quadratic function, 203
- Plateau's problem, 235
- Poincaré lemma, 137, 140
- Poisson kernel, 483, 490
- Poisson's equation, 199
- polarization matrix, 426
- polynomial growth conditions, 269
- positive current, 130
- positive resolvent, 97, 100, 103
- potential, 323
 - Coulomb, 393
 - long range, 393
 - short range, 393
- principle type, 33, 44, 45, 46
- problems of optimization, 287
- progressive wave, 294
- prolongement, 86, 90, 94
- propagation of zeroes, 371
- property (Q), 289
- property (U), 289
- pseudoconvex, 6
 - sets, 6
- pseudo-differential operator, 12, 61, 196
- pseudo-monotone with respect to V , 274
- pseudomonotonicity, 271

- quantized field, 448
- quantum field, 401, 403
- quasilinear, 309
- quasilinear elliptic system, 269
- quasilinear equation, 315
- quasilinear parabolic problem, 340
- Rayleigh-Ritz-Galerkin method,
202
- realization, 114, 115
- recurrence relation, 99
- recursion formulas, 102
- recursion relation, 101
- regularity almost everywhere, 233
- regularity theory,
 L_p , 266
Schauder, 266
- relativistic nonlinear equation, 365
- relativistic wave equation, 365, 441
nonlinear, 365
- Rellich Compactness Theorem,
226, 316
- removable singularity theorem for
 ∂ , 130
- renormalization, 401
mass, 405
super-, 407
- resolvent,
positive, 97, 100, 103
sequence, canonical, 99, 101, 102
- resolvent initial values, 99, 101
- Ricci curvature, 309, 310, 311, 322
- Riemann-Hilbert problem, 142
additive, 138
- Riemannian metric, 321
- rotational symmetry, 438, 439
- scalar curvature, 261, 322, 391
- scale of Banach space, 195
- scattering, 153, 445, 455
- scattering frequency, 156
- scattering operator, 367
- Schauder regularity theory, 266
- Schrödinger operator, 393
- second-order, selfadjoint, C^∞ elliptic
differential operator, 71, 145, 147
- semiboundedness, 114
- semicontinuity,
lower, 288
upper, 289
- semi-Fredholm operator, 227
- semilinear elliptic partial differential equation, 264
- semipositive holomorphic line
bundle, 131
- shift vector field, 310, 322, 323
- shock wave, 293
- short range potential, 393
- simple, 127
eigenvalue, 72
- singular equation, 104
- singular hyperbolic system, 441,
454, 475
- singular integral operator arising
from hyperbolic equation, 479
- singular perturbation problem, 337
- singular set, 253
- singular support, 42
- S -matrix, 456
- Sobolev class, 309, 310, 315
- Sobolev imbedding theorems, 264
- Sobolev inequality, 208
- solutions analytiques, 88
- solutions holomorphes, 85
- solutions hyperfonctions, 91
- Sonine formulas, 102
- Sonine integral formula, 100
- space-body transition, 323
- spacetime, 309
- spectrum,
helicity, 443
mass, 443
spin, 443
- Spencer cohomology group of a
differential equation, 381

- Spencer cohomology group of a transitive Lie algebra, 384
 Spencer complex, 126
 Spencer sequence, 221
 spherical harmonics, 389
 spin manifold, 17, 20, 391
 spin spectrum, 443
 stable hyperbolic, 164
 state equation, 287
 stationary state for nonlinear wave equation, 261
 steady fall, 421
 steady falling motion, 421
 Stokes flow, 421, 429, 431, 433
 strictly hyperbolic system, 309, 311
 strong ellipticity, 246
 strongly elliptic, 114
 strongly nonlinear, 269, 273
 strong maximum principle, 216
 structure theorem for set of finite Hausdorff measure, 252
 Sturm-Liouville theory, 71
 subcoercivity assumption, 285
 subelliptic, 34, 38, 40, 45, 46, 126
 at a point, 126
 subharmonic initial values, 97
 suitable viscosity matrix, 294
 uniformly, 301
 super-renormalizable, 407
 surface, minimal, 353
 symmetric derivative, 486
 symmetric hyperbolic system, 309, 315
 symmetry, 437
 axial, 439
 rotational, 438, 439
 symmetry group, 325
 systèmes hyperboliques nonstricts, 85
 tangential Cauchy-Riemann complex, 105
 tangential Cauchy-Riemann operator, 136
 terminal speed, 429, 430
 theory of capillarity, 5
 trace, 1, 322
 trajectory, 371
 of a collection \mathcal{L} of analytic vector fields, 371
 transitive Lie algebra, 382
 Spencer cohomology group of, 384
 transversal elliptic operator, 11, 12, 106
 transversal index, 11, 12
 Trudinger inequality, 390
 $2m$ -order elliptic differential operator, 113
 uniformly suitable, 301
 unilateral constraint, 288 T
 upper semicontinuity, 289, 486
 vanishing theorem, 141
 variation measure, 250
 variational inequality, 285, 353
 variational principle, 429
 variational problems in parametric form, 231
 vector field, 61, 323
 viscosity, 294
 parameter, 300
 viscous fluid, 421
 von Neumann algebra, 183
 wave equation, 319, 320
 nonlinear, 404
 relativistic, 365, 441
 stationary states for nonlinear, 261
 wave front set, 11, 43
 wave operator, 393
 modified, 393

- weakly advanced fundamental T
solution, 454
- weakly degenerate zero, 72
- weakly retarded fundamental
solution, 454
- Weinstein's recursion relations, 99
- well-posedness, 136
- Wightman distribution, 417
- Yang-Feldman equations, 453
- zero,
propagation of, 371
weakly degenerate, 72
- zero set, 71
- zeta function, 15

