

SUBJECT INDEX

- Absolute temperature** 748
 Accessibility 350
 Action functional 660, 663, 667, 671, 677, 681, 686, 689, 699
 Action integral 658-670, 688
 Adjoint operator 478
 Affine space 78, 185
 Algebraic basis 8-10
 Algebraic dual (*see* dual space)
 Alternating k -linear functional 24, 28, 213, 214, 220
 Alternating multilinear functional 24
 Alternation 26, 27, 387
 Ampère's law 732
 Analytical manifold 75, 80, 82, 87, 89, 123
 Antiderivation 227
 Antixact form 336-340, 359, 360
 Arc 63, 274, 284, 388, 441, 446, 699
 Arc-connected 63
 Atlas, 72, 74, 77, 80, 84, 89, 94, 99, 105, 127, 129, 169, 262, 328, 366, 407, 427, 437, 463, 488
 compatible 74, 94
 equivalent 74, 75
 Attitude matrix 358
- Bäcklund transformation** 537
 Balance forms 524, 530, 579, 597, 664-666, 668
 Balance ideal 524, 529, 534, 536, 565, 594-597, 605, 612, 616, 622
 isovector fields 521, 524, 536, 594, 606, 612, 634
 Barycentric coordinates 417
 Bases induced by the volume form 237, 242, 257, 265, 269, 278-281, 299, 442
 Benjamin-Bona-Mahony equation 694
 Betti number 461, 465, 482, 483, 387
 Bianchi identities, 387
 contracted 392
 Bilinear form, 13, 48, 49, 468, 476, 482, 483
 Bilinear functional (*see* bilinear form)
 Black hole 396
 Boundary layer 552, 568
 Boundary of a set 55
- Boundary operator 421, 422, 429, 466, 467
- Calculus of variations** 658, 663
 Canonical coordinates 191, 702, 710, 714, 716, 721
 Canonical projection 62, 87, 569
 Canonical symplectic form 702
 Canonical system 585, 588, 591, 595, 597, 598, 601
 Canonical transformation 710, 711, 716, 720-724, 749
 Carathéodory's theorem 350
 Cartan annihilators 585, 589, 592
 Cartan connection 377-380
 moving frame 365, 377, 384, 389
 Cartan form 661, 662
 Cartan's lemma 226
 Cartan magic formula 293, 294, 332, 512, 571, 662
 Cartan's theorem 307, 309, 491
 Cartesian product 4, 19, 29, 48, 59, 66, 77, 130, 169, 176, 178, 209, 415, 419, 484
 Cauchy-Bunyakowski-Schwarz inequality 68, 69, 476
 Cauchy sequence 65, 68
 Central motion 728
 Chain complex 423, 466
 Chain rule 118, 124, 144, 211, 255, 366, 367, 370, 523, 628, 747
 Chains 416, 418, 421, 423, 427, 429, 433, 434, 466
 Characteristic curve 493, 496
 Characteristics 164, 310, 448, 496, 551, 565, 569, 598, 603, 726
 Characteristic strip 493
 Characteristic submanifold 312
 Characteristic subspace 247-250, 253, 305-309, 312-315, 499, 588
 Characteristic vector field, 312
 of an exterior form 246, 247, 252
 of an ideal 247, 249, 252, 305, 308, 311, 492, 496, 499, 538, 574, 588, 592
- Chart, 71-75, 82-65, 68-71, 82-89, 101-103, 253, 321, 407, 435, 474
 coordinates 71, 73, 98, 102, 104

- coordinate functions 71, 78, 99, 110, 116,
 125, 133, 321
 coordinate cover 66, 71, 119, 454, 490,
 511, 604, 616, 647, 665, 680, 701, 717
 local coordinates 71, 98, 116, 136, 159,
 183, 209, 253, 290, 343, 407, 423, 488,
 569, 657, 708, 720
 Christoffel symbols,
 first kind 389
 second kind 368, 377, 389, 391, 700
 Closed ball 65-67, 70, 72
 Closed form 267, 269, 298, 334, 343, 347,
 349, 434, 438, 460-465, 473, 481, 706,
 707
 Closed ideal 286, 288, 302, 305, 307, 312,
 314, 491, 500, 510, 571, 573, 587, 590,
 593, 595, 598
 Closed set 53-55, 60, 62, 65, 79, 179, 463
 Closure of a set 54, 55, 57, 72
 Coboundary operator 423, 467, 471
 Cochain complex 14, 269, 423, 460, 467,
 470, 471
 Cochain homomorphism 14, 15, 17
 Cocycle 423, 467
 Co-differential 282, 286, 398, 399, 477, 480
 Cohomology class 17-19, 460, 467, 481-483
 Cohomology group 17, 19, 460, 465-467,
 469, 470, 481, 482, 484
 Commutator 146, 149, 157, 160, 187, 381,
 383, 396
 Compact manifold 135, 466, 476, 478, 479
 Compactness 56, 57, 72
 Compact topological space 56, 70
 Complete ideal 306, 308
 Complete vector field 135, 171
 Configuration manifold 697-701, 727, 741
 Conformal operator 477
 Congruence 139, 142, 145-148, 151, 155,
 158, 190, 290, 592
 Conjugate linear 68
 Connected manifold 78, 191, 203, 407, 461,
 465, 466
 Connected spaces 63, 64, 71, 179, 571
 Connection 1-forms 384
 Conservation laws 448, 451-453, 458-459,
 510, 669, 673, 677-679
 Conservation of energy 459, 679, 709, 720
 Conservative mechanics 696, 724
 Constraints, 697-698, 716
 anholonomic 697
 holonomic 697, 698
 rheonomic 697, 716
 scleronomic 697-699
 Contact forms 490, 507, 523, 524, 581,
 605, 658, 666
 Contact ideal, 491, 500, 506, 521, 524, 528,
 533, 538, 553, 564, 577, 579, 581, 584,
 589, 593, 606, 611, 616, 619, 621, 658,
 661, 664, 671-673, 680-682, 689-691
 isovector fields 500, 506, 510, 606, 611,
 612, 621, 681
 Contact manifold 490, 492, 500, 520, 559,
 569, 586, 658, 665, 680, 681
 Continuous mappings 51-64, 70-72, 76, 79,
 97-100, 102, 127, 135, 335, 604, 663
 Contractible manifold 328, 334, 461
 Contraction 24, 212, 237, 275, 374, 391,
 498, 503, 505, 627, 630, 631, 641, 648
 Contravariant vectors 118, 209, 210, 270,
 366, 444, 739
 Convex set 8, 9, 48, 328, 329, 416, 472, 474
 Coordinate basis 119
 Cotangent bundle 119, 209, 250, 366, 370,
 388, 701-703
 Coulomb's law 730, 732
 Covariant derivative 279, 366, 368-372, 374,
 375, 377-380, 385, 388, 391, 397, 399
 Covariant vector 209, 368, 369, 374, 701
 Covector 209, 214
 Current form 673
 Curl 264, 265, 323, 446, 737, 741
 Curvature operator 376
 Curvature 2-forms 384
 Curvature tensor 375, 377, 380, 381, 387,
 390, 394, 396, 398, 403
 Cycle 422, 423, 434, 466-468, 475, 482

**Darboux class 342, 344, 345, 347-350, 702
 744, 745**
 Darboux' theorems 344, 349
 Dense set 55, 56, 109
 de Rham algebra 461, 462
 de Rham cohomology group 460, 466, 473
 de Rham homomorphism 469, 472
 de Rham manifold 472-475
 de Rham's theorem 469, 474, 475
 Derivation 116, 152
 Diffeomorphic manifolds 98, 101
 Diffeomorphisms 98, 101, 122, 124, 126,
 133, 138, 142, 158, 178-181, 187, 191,
 194, 255-258, 317, 355, 453, 462, 506,
 510, 536, 557, 644, 711-715
 Differentiable curve 110, 133, 414
 Differentiable manifolds 51, 70, 74, 77, 90,

- 93, 95, 97, 100, 102, 104, 108, 110, 112, 118, 120, 123, 127, 129, 131, 133, 142, 153, 167, 253, 327, 334, 349, 369, 406, 415, 423, 429, 435, 438, 459, 698, 702
- Differentiable mapping, 71, 93, 98, 110, 120, 123-125, 131, 152, 197, 266, 274
- its rank 102-110, 200, 422, 573
- Differentiable singular homology group 466
- Differentiable singular simplex 420-422, 424, 430, 472
- Differentiable structure 74, 77, 90, 93, 101, 105, 127, 209, 211, 460
- Differential ideal (*see* closed ideal)
- Differential of a mapping 120, 124, 126, 129, 131, 133, 150, 152, 155, 163, 181, 188, 191, 195, 199, 253, 256, 259, 422
- Diffusion 449, 538, 665
- Direct sum 6, 35, 36, 215, 222, 339, 461
- Disconnected spaces 63, 83, 86, 177, 461
- Disjoint sets 5, 55, 57, 61, 63, 112, 127, 143, 153, 177, 460, 467, 472, 474
- Disjunct subspaces 6
- Distributions, 153, 155, 163, 164, 166, 259, 589, 596
- completely integrable 156
- integral submanifold 156
- involutive 154, 156, 158-161, 163, 166-168, 192, 259, 297, 307, 309, 312, 589
- Divergence 265, 282, 447, 688, 731, 740
- Divergence formula 445
- Divergence theorem 459, 523
- Duality pairing 13
- Dual space 28, 29, 32, 125, 208, 272, 317-319, 389, 423, 467, 468, 472, 475
- Eiconal equation 494**
- Einstein tensor 392
- Elasticities 454, 558
- Electromagnetic fields, 731, 737, 742
- scalar potential 742
- vector potential 742
- Embedding 105, 108, 123, 155, 156, 329, 463, 481
- Emden-Fowler equation 761
- Energy-momentum tensor 392, 393, 668
- Entropy 747
- Equivalence class 5, 17-19, 61, 74, 87, 112, 114, 117, 120, 406, 411, 460, 467-468, 473, 475, 481-483
- Equivalence group 604, 612, 628, 644
- Equivalence relation 5, 61, 74, 87, 112, 114, 406, 460, 466
- Equivalence transformations 604, 606, 616, 628, 634, 639, 644-646, 650, 655
- Euclidean space 64, 66, 70-72, 78, 112, 123, 329, 340, 369, 414, 416, 419, 424, 489
- Euler-Lagrange equations 663, 664, 668, 669, 673, 675, 677, 687-691, 699
- Euler-Lagrange forms 663-666
- Euler-Poincaré characteristic 461, 465, 483
- Exact forms 267, 269, 298, 334, 434, 460, 462, 464, 465, 481
- Exact sequences 14-18, 470, 471
- Exponential mapping 139, 147, 190, 682
- Exponential operator 137, 138, 151
- Exterior algebra 1, 33, 35, 222, 226, 236, 244, 247, 255, 260, 268, 278, 280, 286, 288, 290, 293, 298, 301, 304, 306, 312-317, 331, 339, 446, 460, 477, 507, 524, 570, 587, 605, 658
- Exterior derivative 261-267, 269, 278, 281, 285-287, 289, 293, 299, 304, 309, 319, 339, 352, 354-358, 360, 386, 398, 429, 436, 443, 446, 477, 486, 489, 511, 573, 605, 702, 707
- Exterior differential equations 230, 352, 355, 360-362, 387
- Exterior differential form 71, 214, 220-222, 398, 429, 489, 500, 604
- Exterior equations 258, 306-308, 313, 315, 350, 352, 734, 736
- Exterior form 29, 33, 37, 46, 214
- Exterior normal 435, 444, 445, 459
- Exterior product 29, 33-36, 43-45, 213-215, 222, 224, 226
- Exterior system, 248, 252, 306-309, 311
- completely integrable 308, 309, 311, 312, 314, 350, 590, 596, 745, 748
- Externally oriented submanifold 411, 413
- Faraday's induction law 732**
- Fibre bundle 127, 129, 507
- base 127, 129, 130
- fibres 127, 129, 130, 587
- First countable space 54, 65
- Five lemma 15, 474
- Flow 133, 135, 139, 141-143, 147, 190, 290, 297, 301, 315, 397, 439, 451, 518, 563, 568-570, 659, 672, 681, 708-710, 719
- Fokker-Planck equation 656
- Foliation 160, 590, 593, 594, 596, 598
- Forms on a Lie group, 317
- Maurer-Cartan forms 319
- right-invariant forms 318

- left-invariant forms 317-319, 326
 Frobenius' theorem,
 for distributions 156, 160, 192, 259
 for exterior forms 309, 312, 362
 Fundamental ideal 492, 521, 524, 538, 563,
 565, 572-575
 Fundamental system of neighbourhoods 54,
 countable 65
- Gauss' law 732**
 General linear group 79, 129, 177, 192, 196
 Generalised characteristics 569, 575
 Generalised coordinates 496, 697, 698,
 702, 709, 717, 722, 724
 Generalised Kronecker delta 27, 28, 45, 50,
 213, 214, 217, 236
 Generalised momenta 496, 700, 701, 709,
 716, 717, 722, 724, 726, 728
 Generalised velocities 698
 Generating function 452, 721, 724
 Generators 190, 245, 250, 301
 Geodesic 373, 374, 401, 700
 Global cross section 130
 Gordon equation 597, 600
 Graded algebra 35, 223, 335, 338, 339, 477
 Gradient 343, 345, 347, 355, 366, 369, 453,
 557, 647, 698
 Gram-Schmidt orthonormalisation 273
 Graph space 489, 493, 505, 509, 510, 536,
 537, 550, 551, 584, 670
 Grassmann algebra 1, 215
 Green-Gauss-Ostrogradski formula 445
 Group, 2, 61, 130, 138, 176-181, 195, 198
 Abelian group 3, 17, 195, 197, 320, 460,
 466
 Group-invariant solution 563, 575
 Group of diffeomorphisms 139, 506, 507,
 536, 644
 Group of local diffeomorphisms 139
- Hamiltonian function 496, 701, 705, 709,
 715-724, 726-728, 748, 749**
 Hamiltonian vector fields 704, 707-710, 712,
 713, 716, 717, 720, 748, 749
 Hamilton-Cayley's theorem 204, 363
 Hamilton-Jacobi equation 495, 725-727
 Hamilton principal function 726
 Harmonic forms 284, 476, 478, 479, 481
 Harmonic oscillator 727
 Hausdorff space 55-57, 60, 65, 67, 71, 168
 Heat conduction 449, 542, 545, 565, 656
 Heine-Borel's theorem 70
- Helmholtz free energy function 747
 Hodge decomposition 479-481
 Hodge dual 243, 269, 227, 279, 285, 476,
 483
 Hodge star operator 280, 477
 Homeomorphic spaces 61, 71, 78-80, 82,
 90, 101, 123, 328-330, 334, 340, 342,
 349, 356, 463
 Homeomorphism 61, 71-73, 75, 77, 80, 82,
 86, 89, 91, 98, 101, 105, 108-110, 114,
 128, 168, 183, 257, 328, 422, 436, 437
 Homologous cycles 466
 Homology class 466
 Homotopy operator 267, 331, 333-336, 339,
 340, 352, 353, 358, 459, 736
 change of centre 340
 Horizontal ideal 588-590, 594-596, 599, 601
 isovector fields 590, 592, 595
 Horizontal module 588, 589
 Horizontal one-form 588
 Hyperelasticity 453, 557, 604, 646, 677, 679
 Hyperspherical coordinates 412, 462, 464
- Ideals,**
 of exterior algebra 244-247, 250, 252, 286
 its closure 286, 288, 302, 314, 491, 500,
 606
 Identity mapping 78, 100, 124, 130, 155,
 181, 194, 197, 332, 712
 Immersed manifold 109, 110
 Immersion 104, 105, 107, 109, 110, 122
 Inaccessibility 359, 745
 Infinitesimal generators 139, 191, 522, 529
 Initial data submanifold 571-575, 579
 Integral of the motion 709, 720, 724, 748-
 750
 Integration of exterior forms 414, 419, 423,
 439
 Interior normal 435
 Interior of a set 54, 91
 Interior point 54, 55, 57, 59, 92, 334, 387,
 663, 675, 676
 Interior product 226, 229, 232, 234, 238,
 242, 247, 249, 251, 256, 296, 324, 586,
 706
 Internal energy function 744, 746
 Invariant,
 form field 298
 function 141
 vector field 151
 Isentropic gas flow 451, 510
 Isometry 204, 403

- Isomorphic spaces 6, 10, 49, 78, 114, 117, 125, 180, 183-185, 190, 320, 467, 469, 472, 475, 481, 483
 Isomorphism 6, 7, 10, 12, 15-18, 48, 78, 114, 119, 122, 124, 126, 129, 180, 183, 185, 187-189, 191, 195, 200, 255, 271, 462, 467-469, 472-475, 481, 483, 704, 707, 721
 Isothermal work function 743, 745
 Isovector fields, 301, 302, 304, 305, 315, 316, 500, 589
 vertical 659-661, 663, 664, 682
Jacobi identity 148, 151, 154, 320, 324, 403, 706, 708
 generalised 218
 Jacobi's theorem 712
 Jacobian 166, 257, 277, 310, 407, 433
 matrix 102-105, 121, 122, 410
 Jet bundle 490
Killing equations 397
 Killing vector field 199, 200, 205, 397, 398
 Klein bottle 84, 85, 87, 88, 484
 k -linear functional 19-22, 24, 25, 77
 Korteweg-de Vries equation 546, 550, 566, 567, 579, 650
 Kronecker delta 12, 27, 498
Lagrange equations 698
 Lagrange multiplier 680, 681, 689
 Lagrangian function 698, 700, 716, 726-728
 Laplace equation 479, 655, 669, 670, 693
 Laplace-Beltrami operator 284
 Laplace-de Rham operator 283, 398, 400, 401, 478
 Leaf 160, 590, 593, 594, 596, 597, 599
 Legendre elliptic integral 600
 Legendre transformation 701
 Leibniz rule 116, 291, 300, 369-371, 379, 382, 383
 Levi-Civita connections 389, 392, 396, 398
 Levi-Civita symbols 31, 236, 239, 243, 277
 Levi-Civita tensors 277, 278
 Lie algebra 149, 155, 180, 183-188, 191, 194, -197, 199, 297, 301, 305, 314, 318-320, 506, 510, 536, 544, 592, 671, 706, 708
 Lie bracket 146, 147, 149, 152, 154, 183
 Lie derivative,
 of form fields 290-293, 295, 298, 303, 307, 332, 397, 501, 521, 530, 610, 614, 662, 683, 709, 719
 of tensor fields 215, 300, 397
 of vector fields 143-146, 148, 151, 155
 Lie group, 176, 178-187, 189, 191, 194-199, 201, 317-320, 506, 510, 518, 539, 604
 adjoint representation 196
 exponential mapping 190, 191
 homomorphism 187-189, 196, 318
 inner automorphism 194
 isomorphism 187-191, 192, 195, 196
 left-invariant vector field 181-183, 185-190, 195, 196
 left translation 180, 185, 186, 188, 317
 one-parameter subgroup 189, 190, 192, 196, 200
 right-invariant vector field 185, 190, 199
 right translation 180, 181, 185, 317
 structure constants 184-186, 189, 192, 297, 302, 319, 320
 structure tensor 184
 subgroup, 129, 178, 179, 188, 192, 194, 197, 198, 200, 507
 normal 179, 198
 transformation group, 197, 302, 500, 519
 acting effectively 197, 200, 205
 acting freely 197, 198, 205
 acting transitively 197, 198, 205
 isotropy group 198, 206
 Killing vector field 200, 206
 orbit 198, 206
 Lie product 146, 148, 154, 158, 187, 195, 199, 302, 305, 308, 377, 587, 592, 706-708, 713
 Linear combination 7-9, 25, 31, 37, 39, 126, 224, 226, 233, 240, 317, 347, 348, 417, 420, 424
 Linear (affine) connection 367-369, 374, 377, 389
 Linear (affine) connection coefficients 367-369, 370, 373, 378, 381, 387-389, 398
 Linearly dependent 7, 8, 25, 69, 226, 345
 Linear functional 10-12, 23, 28, 125, 208, 214, 423, 467, 468, 475, 483
 Linear hull 7, 8
 Linearly independent 7-10, 12, 23, 31-33, 35-39, 41, 43, 78, 118, 122, 153-158, 160, 163, 167, 184, 186, 221, 223-226, 231-235, 238, 240, 242, 246-250, 252, 259, 273, 288, 297, 302, 307-309, 311, 317, 343, 377, 387, 393, 409, 411, 416, 458, 460, 490, 502, 510, 517, 519, 527, 536, 544, 551, 557, 573, 584, 586
 Linear operator, 9-11, 14, 16-18, 39, 76, 115-

- 117, 120, 122, 124, 129, 131, 143, 152,
 163, 167, 181, 188, 191, 195, 199, 255,
 260, 280, 331, 336, 414, 421, 477, 481,
 483, 570, 703, 736
 nullity 10
 null space 9
 range 10
 rank 10
 regular 9
 Linear vector spaces, 2-14, 16, 19-25, 30-32,
 35-37, 42, 46, 66-68, 70, 78, 94, 112-
 115, 117, 124-127, 129, 132, 143, 149,
 155, 182-187, 190, 195, 200, 208-210,
 217, 221, 267, 269, 272, 296, 301, 317,
 418, 421, 423, 460, 466-469, 475-477,
 480, 483, 498, 672
 basis (set, vectors) 8-14, 21-25, 28, 32,
 35-39, 41
 change of basis 13, 23
 dimension 8-10
 dual space (algebraic dual) 8
 Hamel basis 8, 9
 quotient space 5, 6, 15-17, 48, 460, 466
 subspaces, 4-7, 9
 complementary 6, 7, 10
 direct sum 6
 intersection 6
 sum 6
 Liouville form 702
 Liouville's theorems 479, 710
 Local cross section 130
 Locally compact space 57, 70-72, 95, 469,
 470, 474
 Locally contractible manifold 328, 329, 349
 Lorentz metric 402, 739
 Lorenz conditions 742
**Maclaurin series 25, 135, 150, 440, 660,
 682**
 Manifold 51, 70
 Manifold with boundary, 90, 93, 429, 435,
 478
 its boundary 90-93
 its interior 90-92
 Matrix, 11-13, 37, 39, 78, 103, 122, 129,
 177, 196
 antisymmetric 47
 Hermitean 203
 Jacobian 102
 orthogonal 177
 polar decomposition 203
 rank 37, 39, 102, 122, 157, 225, 232, 439
 symmetric 47
 symplectic 702
 unitary 202
 Maurer-Cartan forms 319
 Maxwell equations 731, 733, 736, 738-740
 Maxwell reciprocity relations 744
 Mayer-Vietoris sequence 469-471, 473
 Mayer-Vietoris' theorem 469
 Metric 64
 Metric space, 64-66, 70, 71
 complete 65, 68, 70, 75
 Metric tensor 269-271, 273-276, 280, 285,
 389, 392, 397, 399, 441, 476, 699, 739
 Metric topology 64, 67, 70
 Möbius band 130-132, 409, 413, 416
 Module, 2, 19, 127, 149, 212, 214, 221, 223,
 228, 238, 258, 267, 278, 288, 301, 336,
 373, 406, 460, 471, 507, 585, 592, 618,
 703, 705, 708
 horizontal 588, 589
 Momentum phase space 702
 Monge-Ampère equation 577
 Multilinear functional 19, 20, 23, 24, 210
**Natural basis 119, 126, 146, 159, 208, 221,
 223, 236, 243, 280, 372, 377, 734**
 Navier equations 693
 Navier-Stokes equations 552, 656
 Neighbourhood,
 open 54, 57, 59, 62, 72, 90-92, 108, 134,
 178, 183, 191, 334, 420, 430
 compact 57, 72
 Nilpotent operator 261
 Noether's theorem 670, 673, 676, 689
 Noetherian vector fields 671, 673-675
 first kind 671
 second kind 671
 Non-conservative mechanics 716, 749
 Non-linear wave equation 580, 642
 Norm 66-70, 75, 76, 78, 123, 272, 273, 476
Open ball 64, 65, 67, 70, 72, 328, 329
 Open cover, 56-60, 62, 71, 95-97, 408, 470
 locally finite, 57, 59, 62, 408
 Open mapping 61
 Open set 56-63, 65, 70, 72, 74, 80, 82, 84,
 86, 90, 93, 95, 97, 104-107, 110, 114,
 118, 127, 130, 134, 178, 183, 261, 328-
 330, 334, 336, 340, 342, 349, 352, 355,
 361, 387, 408, 410, 425, 427, 463, 465,
 472, 474, 488, 523, 572
 Open submanifold 77-79, 107, 130, 135,

- 179, 186
 Orbit 133, 198
 Orientable manifold 275, 406, 409, 484, 486
 Orientation, 406, 407, 409, 410, 415, 417,
 421, 695, 711
 negative 407
 positive 407, 417, 435, 437, 444, 463
 Oriented manifold 406-408, 411, 418, 466,
 469, 474, 479-484
 Orthogonal group 177, 194
 Orthogonal vectors 272
 Orthonormal basis 264, 272, 273, 389
 Orthonormal vectors 272, 273

**Paracompact spaces 57, 59, 65, 70, 407,
 408, 428, 438, 470**
 Parallel vector field 374
 Partition 5, 61, 74, 112, 406, 414, 460
 Partition of unity 62, 63, 95, 97, 408, 427-
 429, 437, 470, 471
 Path 63, 64, 350-352, 745
 Path-connected 63, 64
 Pfaff system 308
 Phase space 702, 705, 710, 711, 749
 Poincaré duality 483, 484
 Poincaré form 482
 Poincaré lemma 320, 334, 339, 341, 349,
 353, 463, 465, 472, 665, 714, 721
 Poisson bracket,
 of functions 324, 707-709, 713, 750
 of one-forms 705-707, 714
 Poisson's theorem 750
 Potential function 698, 716
 Product manifold 77, 82, 84, 129, 169, 176,
 197, 205, 489
 Projective space 87, 101, 410, 411
 Prolongations 507, 509, 510, 542, 544, 550,
 583, 584
 Pseudo-Riemannian manifold 272, 402
 Pseudotensor 277
 Pull-back operator 98, 100, 254, 256, 306,
 318, 424, 430, 461, 470, 570, 572, 715,
 721

Quadratic form 41, 42, 44, 45
 Quotient rule 212, 275, 375
 Quotient set 5, 61, 112, 460
 Quotient space 5, 15-17, 48, 62, 87, 460,
 466

**Rank of an exterior form 27-46, 246, 342,
 345, 347, 702, 713, 717**

 Reciprocal basis 13, 21, 24, 28, 37, 125,
 208, 224, 234, 248, 250, 254, 271, 273,
 318, 320, 377, 389
 Recursive form 354, 355
 Refinement, 57
 locally finite 57, 59
 Regular mapping 484, 491, 520, 524, 536,
 564, 658-661, 663, 667, 671, 673, 675,
 680-683, 690
 Relatively compact 57, 58, 96
 Resolvent mapping 259, 315, 325
 Reynolds number 656
 Ricci tensor 391, 394
 Riemann integral 414, 415, 424
 Riemannian connection 389
 Riemannian manifold, 243 269, 272-276,
 279, 323, 325, 388, 392, 398, 441, 476,
 479-484
 complete 272, 275, 402, 441, 476, 699
 incomplete 272, 739
 Riemann-Christoffel tensor 390

Scalar 2
 Scalar (inner) product 68-70, 202, 264, 272,
 409, 411, 476-478, 699
 Schouten's theorem 49
 Schouten-Nijenhuis bracket 218
 Schwarzschild metric 392, 396
 Schwarzschild radius 396
 Second countable space 56, 59, 71, 75, 95,
 123, 469, 474
 Self-adjoint operator 478
 Sesquilinear 68
 Shallow water theory 451, 694
 Short exact sequence 15, 17, 470, 471
 Similarity solution 563-567, 575, 655, 656
 Simple form 36, 39, 44, 224, 232, 235, 345,
 347, 405
 Simplex 417-419, 20
 its oriented boundary 417-419, 421
 Simply connected 84, 185, 191, 484, 486
 Singular chains 421-424, 466
 Singular cohomology class 467
 Singular cohomology group 467
 Singular homology group 466, 467
 Smooth functions 102, 113, 126, 134, 138,
 152, 156, 158, 164, 182, 221, 245, 253,
 301, 321, 489, 507, 510, 522, 526, 530,
 534, 571, 583, 585, 589, 591, 594, 606,
 618, 708, 737
 Smooth manifold 75, 78, 123, 133-135, 176,
 178, 183, 185, 197-200, 208, 211, 220,

- 255, 260, 266, 269, 300, 317, 336, 342,
 366, 374, 420, 422, 425, 427, 435, 461,
 469, 472, 474, 488-490, 657
 Smooth mapping 99, 102-104, 122, 130,
 133, 135, 176, 180, 253, 255, 258, 266,
 300, 335, 414, 425, 438, 461, 464, 469,
 489
 Special linear group 177
 Special orthogonal group 177
 Specific heat 451, 748
 Sphere 79-82, 101, 108, 161, 168, 329, 409,
 462, 465, 466
 Spherical coordinates 79, 284, 409
 Stable submodule 298, 301
 Standard simplex 419-422, 424-426, 430,
 431, 433
 Star-shaped region 328, 331, 334, 340, 349
 State variables 742, 745
 Stereographic projection 81, 170
 Stokes formula 446
 Stokes' theorem, 429, 433, 435, 441, 443,
 445-447, 462, 468, 475, 478, 482, 662,
 676, 683, 688
 on chains 429
 on manifolds with boundary 435
 Stress potential 562, 604, 646, 650, 677
 Structural group 129-131
 Submanifold 105-110, 130, 135, 155, 160,
 167, 177-179, 186, 192, 258, 260, 306-
 308, 313, 350, 409, 411, 414, 422-425,
 427, 438, 441-443, 446-449, 451, 455,
 462, 490, 493, 596, 571, 579, 587, 592,
 594, 596, 601, 648, 697, 717, 743, 745
 Submersion 103, 104, 106, 107, 122
 Support 62, 97, 408, 415, 425, 428, 391
 Symmetry group 536, 550, 556, 563, 679
 Symplectic form 46, 702-704, 709, 715, 749
 Symplectic manifold 702, 703, 705, 709,
 710, 713-715, 717
 Symplectic mapping (canonical mapping)
 711-714
 Symplectic matrix 201, 702

**Tangent bundle, 127-130, 132, 156, 163,
 209, 215, 232, 246, 250, 259, 272, 372,
 377, 407, 409, 411, 413, 435, 439, 494,
 507, 509, 536, 550, 585, 596, 619, 698,
 702**
 Tangent space 112, 114, 117-119, 122, 125-
 127, 143, 145, 150, 153, 155, 181, 184-
 186, 190, 208, 213, 259, 270, 318, 369,
 407, 698
 Tangent vectors 112-116, 118, 124, 189-
 191, 200, 274, 373, 446
 Taylor series 137, 144, 152, 291
 Temperature 538, 742, 745, 746, 748
 Tensor, 21, 210
 contravariant 23, 214, 279, 740
 covariant 22, 24, 29, 213, 220, 269, 388,
 442
 density 277
 mixed 23, 24, 210, 215, 275
 Tensor bundle 211, 213-215
 Tensor product 20, 21, 23, 24, 29, 49, 210,
 212, 215, 300, 317, 371, 372, 382
 Theory of Hodge-de Rham 406, 476
 Thermodynamics 696, 742, 745
 first law 744
 Thermodynamic temperature 746
 Toda lattice 748, 749
 Topological manifold 71, 72, 74, 75, 90
 Topological space, 53-57, 59-64, 70, 71, 87,
 90, 93, 95, 128, 179, 466
 separable 55, 56, 71, 75, 123
 Topology, 53, 55-57, 59-65, 67, 77, 105,
 127, 268, 429, 459-461
 basis 41
 product 42, 51
 relative 53, 56, 57, 60, 63, 90, 91, 93,
 105-107, 110
 Torsion operator 376
 Torsion tensor 375, 380, 385, 390, 396, 401
 Torsion two-forms 384
 Torus 82, 84, 105, 109, 178, 329
 Trajectory 133, 705, 709, 718, 726, 731
 Transversality condition 573, 579

Unimodular group 177
 Unitary operator 477

Variation of a functional 660, 664, 682
 Variation operator 660, 682
 Variational principle 664-666, 663, 693
 Variations 685, 688
 Variational symmetry 670, 674, 675, 677,
 679, 689, 693, 694
 Vectors 2, 6-10, 12-14, 17, 20-25, 28, 30-40,
 66, 69, 71, 76-78, 81, 94, 112-120, 122,
 142, 146, 149, 154, 157, 162-165, 184-
 186, 191, 209, 223, 229, 232, 248, 250-
 254, 270-274, 296, 302, 309, 368, 370,
 376-378, 382, 389, 416, 439, 444, 592,
 707, 721, 731, 739
 Vector fields, 119, 126, 129, 132, 136, 139,

- 141-146, 149-151, 155, 181, 190-192,
196, 199, 215, 226, 229, 233, 247, 249,
259, 265, 270, 283, 290, 293, 295, 297,
300-304, 366, 368, 372, 374, 376, 380,
397, 410, 413, 439, 492, 495, 500, 509,
536, 565, 569, 569-571, 584, 589, 592,
606, 659, 703, 716, 718-721, 734, 737
integral curve 133-135, 138, 141, 155,
161, 189, 200
Velocity phase space 698
Vertical ideal 587, 589
Volume form 223, 236, 240, 257, 265, 275,
278, 280, 285, 299, 406-409, 411-414,
435, 441, 447, 449, 462, 465, 476, 520,
573, 658, 677, 710, 733

Wave equation 486, 644, 646, 656, 742
Whitehead manifold 329
Whitney's theorems 51, 75, 123
Work 696, 743, 744
Wronskian 47

Zigzag lemma 17
Zorn lemma 6, 8