

Index

- accelerated expansion 141–154
- acoustic metric 104
- acoustic mode 107
- ADM conserved quantity 157–183
- ADM equations 210, 211
- ADM mass 232
- Alfvén wave 104, 108
- anastigmatic conjugacy 92
- angular momentum
 - quasi local 160
 - total 161
- anisotropic medium 106
- astigmatic conjugacy 28, 29, 92
- asymptotic coordinate system
 - Cartesian 163, 176
 - collapsing 176
 - Rindler 176, 180
- asymptotic geodesic 6, 18
- asymptotic Killing vector 157–183
- asymptotically flat spacetime 47, 157–183
- attractor 189, 190, 200, 201
- Avez–Seifert theorem 52
- AVTD solution 192, 194, 195

- barotropic fluid 103
- Beig–Ó Murchadha centre-of-mass 171–173, 180, 181
- Beig–Ó Murchadha Hamiltonian 170, 171, 174, 178, 179, 181
- Betti number 60, 67, 72
- Bianchi cosmology 146
- Bianchi identities 110, 208
- biaxial crystal 104
- big crunch singularity 194
- birefringence 101
- BKL conjecture 188, 191–194, 196
- Bolza problem 95

- bounce law 193, 199, 200
- boundary condition 205–221, 233, 242, 251–255, 266
 - constraint-preserving 206, 215, 226–227, 243, 256, 267
 - cosmological 188
 - homogeneous 267
 - maximally dissipative 224, 225, 255, 266
- Busemann function 17–20

- canonical one-form 41
- Cauchy surface 21, 22, 38, 44–46, 87
- Cauchy-Riemann equation 127
- Cauchy problem 101, 109, 205, 206, 219, 252, 253, 266, 267
- causal boundary 35, 47
- causal continuity 87
- causal disconnection 9–14, 30
- causal future 37
- causal simplicity 87
- causal structure 43, 47, 101
- causal vector 107
- causality 7, 36, 38, 45, 79, 87–89
- caustic 28, 45
- centre of mass 157–183
- Chaplygin gas 142, 151, 153
- characteristic conormal 103, 106
- characteristic polynomial 102, 103
- characteristic field 210–213, 215
- characteristic speed 210, 215, 217, 241
- chronological future 37
- chronology 4, 10, 12, 38, 44, 47
- closed timelike curve 10
- co-ray condition 19, 20
- compactification 5
- complementing condition 129, 132
- Condition N 8

- conformal Laplace operator 123
- conformal structure 47
- conformal transformation 6–8, 10, 12, 16, 26
- conjugate point 10, 12, 23–26, 28, 29, 56, 62, 67, 71–75, 79, 90, 92–95
- conormal boundary condition 123
- conserved quantity 157–183
- constraints 117–137, 169, 193, 212, 217, 224, 243–247, 251
 - propagation 205, 218, 235, 266
 - violation 225, 266
- contact structure 35, 41
- continuum mechanics 101–114
- convergence 224
- convergence test 237
- convex boundary 73–74
- convex deformation 8
- convex neighborhood 44
- cosmic censorship 187, 224, 230, 232
- cosmological constant 142
- cosmology 141–154, 187–201
- cotangent bundle 38
- critical point 53–75, 82, 92, 95
- critical phenomena 189, 224
- crystal optics 104
- cut point 9, 10, 22–30

- dark energy 143
- de Sitter space 144
 - stability of 145
- Dirichlet boundary-value problem 117–137
- discretization 224, 236, 237
- disprisonment 15, 16
- distance function 23, 24
- distinguishing spacetime 87, 88
- dual cone 108

- Ehlers–Kundt conjecture 80, 82, 91–92
- Einstein static universe 45, 48
- elasticity 101–114, 127
- elasticity tensor 106
- electrostatics 118
- elliptic boundary-value problem 117–137
- elliptic differential equation 117–137
- elliptic operator 119

- energy condition 8, 45, 85, 146, 148, 150, 151, 153
- energy-momentum
 - quasi local 160
 - total 161
- energy estimate 225, 226, 261
- Euler equations 103
- Euler vector field 39
- event horizon 187, 242
- evolution equation 209, 214, 216, 217, 224, 233, 257
- excision 242
- exponential map 3
- extrinsic curvature 209, 211

- Fermat principle 52, 75
- finite compactness 3, 4
- flatness problem 142, 147
- FLRW metric 141–154
- flux conservative system 259, 260, 262, 264
- focussing space-time 47
- formal adjoint 120
- Fredholm operator 56, 67, 70, 135
- freezing boundary condition 214
- Fresnel surface 104
- Frobenius theorem 40
- future horismos 37

- Galilean metric 104, 105
- gauge condition 251
- gauge wave 257–260, 265
- generic condition 12–14, 21
- geodesic completeness 3, 4, 6–8, 11, 12, 14–17, 20, 21, 28, 79, 80, 82, 89–92
- geodesic connectedness 3, 10, 28, 30, 51, 52, 65–67, 69, 74, 75, 79, 82, 92–95, 97
- geodesic line 12, 17, 19, 20, 30
- geodesic ray 5, 6, 17, 18, 24
- geodesic vector field 39
- global hyperbolicity 4, 7–10, 12, 19, 20, 24, 25, 38, 42–44, 46, 52, 68, 79, 80, 87, 88
- Gowdy model 194–198
- Grassmannian manifold 46, 47
- gravitational lensing 45, 52, 62
- gravitational radiation 251
- gravitational wave 22–30, 79–97

- Green formula 120, 122, 131
 Gromov–Hausdorff theory 30
 group velocity 107
 growing mode 256, 259
 Gödel metric 36, 66
- Hamiltonian function 39
 Hamiltonian constraint 270
 harmonic coordinates 256–258, 267
 Hilbert space 53, 55, 56, 58, 70
 homogenization 146
 homology group 62, 72
 Hopf–Rinow theorem 3, 4, 52, 61
 horizon 88–89
 horizon problem 142, 147
 horosphere 19
 hyperbolic polynomial 102, 103, 106
 hyperbolicity 101, 102, 109
- imprisoned curve 8
 imprisoned geodesic 8, 15
 index form 9
 inflation 141–154
 initial-boundary value problem 206, 207, 209, 214, 215, 218, 221, 224, 226, 243, 253
 initial-value problem 109–113, 205, 252
 initial data 187, 189, 224, 232, 233, 242, 251
 isolated system 251, 254
 isotropization 146
- Jacobi field 25, 41, 43, 44, 56
- Kaluza–Klein theory 230
 Kasner epoch 192, 193
 Kasner model 191, 196, 197
 Kerr metric 74
- lacuna 109
 Laplace equation 117, 129–130
 Laplace operator 117, 123
 lapse and shift 158, 159, 161, 163, 164, 166–168
 Legendre submanifold 35, 42, 45
 light cone 43–45, 47, 48, 81
 limit curve 5, 11
 linking number 43, 44, 47
- linking theorem 60
 Ljusternik–Schnirelmann theory 53, 58, 61, 62, 70, 96
 LMD behavior 192–194, 200, 201
 localized system 157–183
 loop space 62, 70, 72
 Lopatinski-Shapiro conditions 129
 Lorentz force 75
 Lorentz invariance
 – violations of 105
 Lorentzian distance 9–14
 Lorentzian geometry 3–30, 35–49, 51–75, 79–97
 Lorenz attractor 190
- magnetohydrodynamics 104, 107
 Maslov index 75
 maximum principle 122
 Maxwell equations 103, 105
 – premetric 105
 method of lines 236
 metric completeness 3
 microwave background radiation 142
 minimal distortion gauge 127
 minisuperspace 191, 192
 Minkowski space 40, 42, 43
 Mixmaster model 191–194
 Morse index 10
 Morse theory 53–75
 mountain pass theorem 60
- naked singularity 187, 230, 232
 Neumann boundary-value problem 117–137
 Newtonian space-time 35
 non-imprisonment 8, 26
 normal boundary conditions 135
 null geodesic 7, 8, 10, 12–16, 20, 29, 30, 35–49, 75, 81, 92
 null infinity 251
 null separation 43
 numerical dissipation 226, 251, 253, 262, 263
 numerical noise 253, 259
 numerical stability 224, 237, 251, 268
- oblique derivative problem 122
 outgoing radiation 214, 266

- Palais–Smale condition 53, 56–58, 60–63, 68, 69, 72
- perfect fluid 110, 150
- phantom field 152
- phase space of vacuum GR 168
- phase velocity 107
- Poincaré structure 157–183
- Poincaré transformation 161, 181
- Poincaré polynomial 59
- positive mass theorem 128
- power-law inflation 149, 150
- pp-wave 79, 97
- precompactness 65, 66
- pressure waves 106
- principal part of differential operator 118, 123, 124
- principal symbol 103
- proper ellipticity 125, 134, 135
- pseudoconvexity 15, 16
- pseudodifferential reduction 113
- quantum gravity 188
- quasi-time function 28, 83, 88
- quintessence 143, 148
- ray cone 108
- ray velocity 107
- refocussing space-time 46
- Regge–Teitelboim angular momentum 171, 173, 180, 181
- regular hyperbolicity 101–114
- Reissner–Nordström metric 73
- Robertson–Walker metric 14, 141–154
- saddle point theorem 60, 69
- scalar field 150
- Schwarzschild metric 73
- semi-discrete system 225, 236
- semi-Riemannian geometry 51–75
- shear waves 106
- simultaneity 35
- singularity 36
- singularity theorem 12, 21, 187
- sky 42–48
- slow fall-off metrics 169, 178, 182
- slowness surface 107
- Sobolev space 52, 53
- Sommerfeld condition 254, 270
- sphere bundle 42, 44, 45
- splitting Lorentzian manifold 11, 17–22, 30, 68–72
- stable causality 8, 38, 87, 88
- stiff fluid 148
- Stokes system 126
- strict hyperbolicity 103
- strong causality 8, 10–12, 38, 40, 42, 44, 47, 80, 87, 88
- strong ellipticity 125, 132
- strong hyperbolicity 101–114, 205, 209–214, 221
- strong field gravity 191
- summation by parts 225, 259, 260, 262
- supernova 143, 152
- supertranslations 164, 167
- symmetric hyperbolic system 101–114, 212, 224, 225, 227, 236, 241, 243, 255, 256, 268
- symplectic structure 41, 169
- tachyon 142, 152
- tangent bundle 38
- time function 87
- time-orientability 37
- timelike convergence condition 12, 17, 20, 22
- topological sphere theorem 11
- Toponogov theorem 19
- trapped null geodesic 8
- trapped surface 89
- triaxial crystal 104
- twist 193, 194, 199, 200
- twistor 43
- Unruh metric 104
- vacuum cosmology 191
- variational problem 51–75, 82, 92
- Vlassov equation 146, 149
- VTD solution 195, 196, 200
- warped product 8, 14
- wave front 45, 107
- wave front singularity 45
- waveform 251
- weak hyperbolicity 101–114, 271
- well-posedness 251, 254
- Weyl tensor 13
- Whitehead link 44
- winding number 43
- Witten equation 128, 134

Lecture Notes in Physics

For information about earlier volumes
please contact your bookseller or Springer
LNP Online archive: springerlink.com

- Vol.643: F. Strocchi, Symmetry Breaking
- Vol.644: B. Grammaticos, Y. Kosmann-Schwarzbach, T. Tamizhmani (Eds.) Discrete Integrable Systems
- Vol.645: U. Schollwöck, J. Richter, D. J. J. Farnell, R. F. Bishop (Eds.), Quantum Magnetism
- Vol.646: N. Bretón, J. L. Cervantes-Cota, M. Salgado (Eds.), The Early Universe and Observational Cosmology
- Vol.647: D. Blaschke, M. A. Ivanov, T. Mannel (Eds.), Heavy Quark Physics
- Vol.648: S. G. Karshenboim, E. Peik (Eds.), Astrophysics, Clocks and Fundamental Constants
- Vol.649: M. Paris, J. Rehacek (Eds.), Quantum State Estimation
- Vol.650: E. Ben-Naim, H. Frauenfelder, Z. Toroczkai (Eds.), Complex Networks
- Vol.651: J. S. Al-Khalili, E. Roeckl (Eds.), The Euroschool Lectures of Physics with Exotic Beams, Vol.I
- Vol.652: J. Arias, M. Lozano (Eds.), Exotic Nuclear Physics
- Vol.653: E. Papantonopoulos (Ed.), The Physics of the Early Universe
- Vol.654: G. Cassinelli, A. Levvero, E. de Vito, P. J. Lahti (Eds.), Theory and Application to the Galileo Group
- Vol.655: M. Shillor, M. Sofonea, J. J. Telega, Models and Analysis of Quasistatic Contact
- Vol.656: K. Scherer, H. Fichtner, B. Heber, U. Mall (Eds.), Space Weather
- Vol.657: J. Gemmer, M. Michel, G. Mahler (Eds.), Quantum Thermodynamics
- Vol.658: K. Busch, A. Powell, C. Röhlig, G. Schön, J. Weissmüller (Eds.), Functional Nanostructures
- Vol.659: E. Bick, F. D. Steffen (Eds.), Topology and Geometry in Physics
- Vol.660: A. N. Gorban, I. V. Karlin, Invariant Manifolds for Physical and Chemical Kinetics
- Vol.661: N. Akhmediev, A. Ankiewicz (Eds.) Dissipative Solitons
- Vol.662: U. Carow-Watamura, Y. Maeda, S. Watamura (Eds.), Quantum Field Theory and Noncommutative Geometry
- Vol.663: A. Kalloniatis, D. Leinweber, A. Williams (Eds.), Lattice Hadron Physics
- Vol.664: R. Wielebinski, R. Beck (Eds.), Cosmic Magnetic Fields
- Vol.665: V. Martinez (Ed.), Data Analysis in Cosmology
- Vol.666: D. Britz, Digital Simulation in Electrochemistry
- Vol.667: W. D. Heiss (Ed.), Quantum Dots: a Doorway to Nanoscale Physics
- Vol.668: H. Ocampo, S. Paycha, A. Vargas (Eds.), Geometric and Topological Methods for Quantum Field Theory
- Vol.669: G. Amelino-Camelia, J. Kowalski-Glikman (Eds.), Planck Scale Effects in Astrophysics and Cosmology
- Vol.670: A. Dinklage, G. Marx, T. Klinger, L. Schweikhard (Eds.), Plasma Physics
- Vol.671: J.-R. Chazottes, B. Fernandez (Eds.), Dynamics of Coupled Map Lattices and of Related Spatially Extended Systems
- Vol.672: R. Kh. Zeytounian, Topics in Hypersonic Flow Theory
- Vol.673: C. Bona, C. Palenzuela-Luque, Elements of Numerical Relativity
- Vol.674: A. G. Hunt, Percolation Theory for Flow in Porous Media
- Vol.675: M. Kröger, Models for Polymeric and Anisotropic Liquids
- Vol.676: I. Galanakis, P. H. Dederichs (Eds.), Half-metallic Alloys
- Vol.678: M. Donath, W. Nolting (Eds.), Local-Moment Ferromagnets
- Vol.679: A. Das, B. K. Chakrabarti (Eds.), Quantum Annealing and Related Optimization Methods
- Vol.680: G. Cuniberti, G. Fagas, K. Richter (Eds.), Introducing Molecular Electronics
- Vol.681: A. Llor, Statistical Hydrodynamic Models for Developed Mixing Instability Flows
- Vol.682: J. Souchay (Ed.), Dynamics of Extended Celestial Bodies and Rings
- Vol.683: R. Dvorak, F. Freistetter, J. Kurths (Eds.), Chaos and Stability in Planetary Systems
- Vol.685: C. Klein, O. Richter, Ernst Equation and Riemann Surfaces
- Vol.686: A. D. Yaghjian, Relativistic Dynamics of a Charged Sphere
- Vol.687: J. W. LaBelle, R. A. Treumann (Eds.), Geospace Electromagnetic Waves and Radiation
- Vol.688: M. Rubi, M. C. Miguel (Eds.), Jamming, Yielding, and Irreversible Deformation in Condensed Matter
- Vol.689: W. Pötz, J. Fabian, U. Hohenester (Eds.), Quantum Coherence
- Vol.691: S.S. Abdullaev, Construction of Mappings for Hamiltonian Systems and Their Applications
- Vol.692: J. Frauendiener, D.J.W. Giulini, V. Perlick (Eds.), Analytical and Numerical Approaches to Mathematical Relativity