Index

A
Absolute space, 18
Accelerated expansion, 321
Accelerated frame, 108, 109, 112
Accelerated frame hyperbolically, 108
Accelerated reference frame, 89, 112
4-acceleration, 272
Acceleration in a rotating reference frame, 142
Acceleration of gravity, 14, 16, 135, 192, 194, 271, 283
Acceleration of particle in non-rotating frame, 142
Acceleration of particle in rotating frame, 142
Acceleration scalar, 272
Action, 127
Adiabatic, 327
Age-density relation, 384, 496
Age of the universe, 311, 315, 383, 489
Age-redshift relationship, 329, 341
Ampere's circuit law, 54
Angular acceleration, 95
Angular momentum, 228
Anisotropic universe models, 351
Anisotropy parameter, 352
Antisymmetric tensor, 78, 86, 119, 426
Antisymmetrization, 80
Archimedean spiral, 99
Atmospheric mesons, 421

B
Basis forms, 178
Basis vector, 71, 147
Bergmann, 393
Bianchi
  1st identity, 185, 186
    component form, 185
  2nd identity, 186, 201
Bianchi type-I, 351
Big Bang, 275
Big Bang cosmology, 361
Big Rip, 351
Binary system, 265, 266
Black body radiation, 44
Black hole, 221, 222, 263, 271, 273, 476
  horizon, 271
  radiation, 273
  temperature, 273
Blueshift, 56
Boltzmann's constant, 273, 363
Boost, 35
Born-rigid motion, 108
Born-stiff motion, 108
Boyer-Lindquist coordinates, 276, 280, 299
Boyer-Lindquist coordinate system, 277, 281, 480, 482
Brill, 19, 377

C
Canonical momentum, 128
Cartan
  surface curvature, 183
Cartan connection, 147, 150
Cartan formalism, 183, 211
Cartan's structure equations, 178, 395
Cartan structure equations 1st, 148, 149, 178, 185, 212, 395, 456
Cartan structure equations 2nd, 178, 179, 185, 186, 212, 397, 457
Cartesian basis, 169

Ø. Grøn, *Introduction to Einstein's Theory of Relativity*,
Undergraduate Texts in Physics, https://doi.org/10.1007/978-3-030-43862-3

Cartesian coordinates, 47, 73, 75, 155, 164, 169
Cartesian coordinate system, 23, 34, 49, 61, 66, 67, 115, 116, 123, 140, 152, 177, 198, 444
Causal, 76
Causal mass, 378, 380
ΛCDM universe, 380
Centrifugal acceleration, 143
Centrifugal barrier, 230
Centrifugal force, 19, 95
Centripetal acceleration, 99, 105
Chaotic inflation, 375
Cherenkov radiation, 57, 422
Chirp, 260, 267
Chirp mass, 263, 264
Christoffel, 122
Christoffel symbols, 122, 130, 135, 141, 142, 146, 155, 171, 177, 189, 190, 192, 195, 215, 244, 272, 282, 402, 449, 459, 475
Christoffel symbols in coordinate basis, 123
Christoffel symbols physical interpretation, 215
Christoffel symbols rotating reference frame, 141
Classical electron radius, 300
Clock, 78, 98
Codifferential, 157, 166
Cohen, 19, 377
Coincidence problem, 348
Commutator, 68, 143, 149, 155
Co-moving coordinate system, 64, 311
Conformally flat, 295, 296
Conformal time, 331, 383, 489
Connection coefficients, 123, 140, 142, 144, 145, 148, 176, 188
Connection coefficients in coordinate basis, 123
Connection coefficients rotating reference frame, 140
Connection forms, 147, 177, 183, 212, 457
Connections coefficients, 177
Conservation energy-momentum, 197
Conservation of mass-energy, 198
Constants of motion, 128, 156, 171, 453
Continuity equation, 197, 198, 366
Contraction, 69, 86, 149, 168, 177
Contractions of tensors, 427
Contravariant components, 74
Contravariant tensor, 70
Convective derivative, 151, 152
Coordinate basis, 120, 143, 150
Coordinate basis connection coefficients, 123
Coordinate basis forms, 161
Coordinate basis vector, 64, 66, 67, 141, 161, 179
Coordinate clocks, 24, 94, 109, 141, 216
Coordinate cyclic, 128, 129
Coordinate Gaussian, 123
Coordinate singularity, 239
Coordinate system, 23, 64
Coordinate time, 24, 98, 109, 112
Coordinate transformation, 65, 87, 91, 93
Coordinate vector, 62
Coriolis acceleration, 143, 193
Cosmic fluids, 317
Cosmic Microwave Background (CMB), 372
Cosmic microwave background radiation, 372
Cosmic red-shift, 323, 326
Cosmic time, 311
Cosmological constant, 204, 242, 318, 367, 462, 471, 484
Cosmological horizon, 359
Cosmological red-shift, 315–317
Cosmology, 311
Covariance principle, 17, 122
Covariant, 18
Covariant components, 86
Covariant derivative, 119, 122, 144–146, 153, 189
Covariant differentiation, 119
Covariant directional derivative, 124, 140, 144, 145, 153, 173, 188, 453
Covariant equation, 72
Covariant Euler-Lagrange equations, 127, 128
Covariant tensor, 70
Critical density, 345
Curl, 157, 160–162, 445
Current form, 166
Curvature, 173, 195, 456
  forms
    of surface, 183
  Gaussian, 183, 184
  geodesic, 181
  normal, 181
  principal, 182
  Ricci, 177
  Riemann tensor, 175
  surface (Cartan formalism), 183
Curvature coordinates, 211, 216, 220, 222, 226

Curvature forms, 177, 212, 457
Curvature of space, 196
Curvature scalar, 457
Cyclic coordinate, 128, 228, 250
Cylinder conditions, 394
Cylinder coordinates, 93, 225
Cylinder dimension, 404

D
D'Alembertian wave operator, 162, 164
D'Alembert's wave operator, 157, 244
Deceleration parameter, 324, 342, 385, 494, 498
Deflection of light, 211, 236
Density parameter, 322, 345, 386, 499
de Sitter spacetime, 241, 321, 387, 471
de Sitter universe, 505
de Sitter universe models, 386, 501
Determinant, 81
Differential forms, 211
  curvature
    of surface, 183
Differential forms connection, 212
Differential forms curvature, 212
Differential forms, directional derivatives of, 145
Differential geometry, 179
Differential operator, 66, 140, 169, 444
Differentiation covariant, 124
Differentiation of forms, 119
Dimension, 59
Dirac delta function, 6
Directional derivative, 66, 140, 153, 156, 179
Distance coordinate, 211
Distance physical, 211
Divergence, 157, 162, 167, 170, 198, 445
D'Lambertian wave operator, 159
Domain wall, 309, 485
Doppler effect, 26, 311, 326, 418, 477
Dragging angular velocity, 251, 278
Dual, 82, 83, 160, 161, 167
Dual forms, 84, 169, 442
Dust, 200, 205, 317, 321, 328, 348
Dust dominated universe, 331
Dust-dominated universe model, 331, 333

E
Earth, 12, 20, 33, 34, 117, 226, 227, 232, 253, 264, 412, 413
Earth-Moon system, 21, 413, 414
Eccentricity, 266
Eddington, 255
Eddington–Finkelstein coordinates, 216, 219
Eddington-Finkelstein coordinate system, 220
Effective potential, 230
Ehrenfest's paradox, 89
Einstein, 15, 17, 19, 23, 31, 44, 45, 52, 99, 197, 201, 393
Einstein–de Sitter, 333
Einstein–de Sitter model, 342
Einstein–de Sitter universe, 378, 379, 490
Einstein field equations, 202, 241
Einstein's constant of gravity, 202
Einstein's curvature tensor, 201, 211, 285, 484
Einstein's field equations, 197, 201, 202, 206–208, 238, 243, 244–247, 255, 275, 284, 285, 295, 326, 462, 497
Einstein spaces, 204
Einstein's theory, 211
Einstein synchronization, 92, 101
Einstein synchronized, 25
Einstein tensor, 202, 211, 213, 284, 469
Electrical field, 53
Electric field, 209
Electric field strength, 163
Electricity, 51
Electric scalar potential, 163
Electromagnetic current form, 165
Electromagnetic field, 51, 167, 168, 201, 207
Electromagnetic field form, 163, 166
Electromagnetic field tensor, 207
Electromagnetic potential form, 162
Electromagnetic vector potential, 163, 207
Electromagnetic waves, 33, 167
Electromagnetism, 162
Ellipse, 266
Embedding, 225
Embedding of the Schwarzschild metric, 225
Emission point of time, 329
Empty space, 204
Energy, 44, 47
Energy conservation, 168
Energy-momentum conservation, 197, 208, 326
Energy-momentum tensor, 197–200, 205, 207, 209, 210, 238, 246, 247, 460
Eötvös, 15
Equation of continuity, 167, 210, 460
Equation of geodesic deviation, 189, 196
Equation of state, 462
Equatorial plane, 229
Euclidean geometry, 94

Euclidean plane, 87, 155, 428
Euclidean space, 169, 442
Euclidean 3-space, 82, 161
Euclidean spatial geometry, 323, 361
Euler equation, 240
Euler equation of motion, 198, 199, 210, 460
Euler–Lagrange equation, 119, 128, 131, 135
Event, 23, 77
Event horizons, 386, 501
Expansion, 153
Exterior derivative, 119–121, 147, 150, 157–161, 163, 165, 166, 178
Exterior differentiation, 150
Exterior Schwarzschild metric, 215
Extrinsic curvature tensor, 298

F
Fabry-Pérot cavities, 260
False vacuum, 362
Fermi gamma ray space telescope, 269
Field equations Einstein, 202
Field equations vacuum, 204
First order phase transition, 363
Flamm paraboloid, 226
Flatness problem, 360, 365
Flat spacetime, 76
Flat universe model, 319
Force, 47–49
Form-components, 80
Form-invariant, 18
Forms, 59, 78, 119
Four-acceleration, 62
Four momentum, 61
Four-vectors, 85, 424
Four-velocity, 60, 65, 76
Four-velocity identity, 76
Free fall, 15, 217
Freely falling reference frame, 15
Free particle, 130, 135
Frequency, 116
Friedman-Lemaître Eq., 328
Friedmann–Lemaître, 338
Friedmann–Lemaître model, 342, 348
Friedmann–Lemaître universe model, 347
Friedmann equation, 366, 488
Friedmann-Lemaître equations, 319, 331, 332
Friedmann metric, 488
Friedmann models, 360, 362, 365
Friedmann's 1st equation, 500

G
Galilean kinematics, 23
Galilei, 14
Galilei transformation, 18, 35
Galileo, 1
Gamma ray burst, 269
Gauge transformation, 164, 394
Gauss
  curvature, 183
  theorema egregium, 184
Gauss' equation, 180
Gaussian coordinates, 123
Gaussian curvature, 183, 184, 457
Gauss integral theorem, 6
Gauss' law, 410
Gauss's integral theorem, 246
General principle of relativity, 17
General theory of relativity, 1, 16, 19, 62, 95, 119, 122, 123, 215, 232, 233, 243, 266, 290, 305
Geodesic
  curvature, 181
Geodesic curve, 78, 125, 130, 156, 181, 206, 448
Geodesic deviation, 188, 257
Geodesic equation, 125, 171, 312, 453
Geodesic normal coordinates, 189
Geodesic postulate, 204
Geodesic world lines, 133
Geometrical optics, 118, 439
GPS, 242, 473
GPS-satellite, 474
Gradient, 157, 159, 161, 170, 444
Gravitation, 18
Gravitational acceleration, 214
  Tolman-Whittaker expression, 284
Gravitational antenna, 258
Gravitational collapse, 382, 486
Gravitational field, 4, 16, 95, 112, 118, 138, 192, 243, 438
Gravitational force, 412
Gravitational frequency shift, 211
Gravitational mass, 283
Gravitational mass–density, 321
Gravitational potential, 193, 246, 411
Gravitational radiation emission, 266
Gravitational redshift, 140
Gravitational self energy, 295
Gravitational shift of wavelength, 326
Gravitational time dilation, 89, 98, 99, 112, 134
Gravitational wave detector, 264

Gravitational waves, 243, 245, 253–257, 260, 263, 266
Gravito-electric' field, 252
Gravitoelectromagnetic fields, 253
Gravitoelectromagnetism, 251
Gravitomagnetic clock effect, 281, 483
Gravitomagnetic field, 252
Gravitomagnetic vector potential, 251
Gravitomagnetism, 243
Gravity, 119
Gravity probe B, 253
Guth, Alan, 363

H
Hafele-Keating experiment, 232
Hamiltons principle, 127
Harrison-Zel'dovich spectrum, 373
Hawking, 273
Hawking radiation, 271, 273
Heat capacity of black hole, 274
Heisenberg uncertainty relationships, 200
Higgs field, 361, 362
Higgs mechanism, 361
Hilbert, 204, 206
Hilbert's variational principle, 206
Hodge Laplacian, 158
Horizon, 113, 220, 222, 271, 277, 380, 471
Horizon problem, 358, 364
Horizon radius, 379
Hubble age, 315, 334, 340, 342, 359, 360, 379, 490, 494
Hubble constant, 314, 320, 322, 339
Hubble flow, 305, 308, 315
Hubble-Lemaître expansion law, 311
Hubble-Lemaître law, 314, 315
Hubble length, 315, 323
Hubble parameter, 314, 320, 322, 342, 348, 350, 367, 368, 383, 489, 494
Hubble slow roll parameters, 368
Hydrostatic equilibrium, 8
Hyperbolically accelerated frame, 107
Hyperbolic motion, 41–43

I
Incompressible star, 7, 288
Inertial dragging, 243, 250, 253, 271, 277, 377, 378, 405
Inertial dragging angular velocity, 377
Inertial effects, 193
Inertial forces, 19
Inertial frame, 16, 47, 93, 108, 123, 198, 250
Inertial reference frame, 16, 40, 41, 64, 123, 133, 140
Inertial rest frame, 116
Infalling coordinates, 382
Inflation, 363
Inflationary era, 364, 366, 372, 377
Inflationary model, 363
Inflationary universe models, 361
Inflaton field, 366, 367, 375
Inflaton potential, 368
Inhomogeneous universe models, 355
Instantaneous rest frame, 92
INTEGRAL telescope, 269
Interference, 99
Interference fringes, 99
Interferometer, 260, 264
Internal coordinate transformation, 91
Internal Schwarzschild solution, 283
Internal Schwarzschild space-time, 289
Interval, 37, 40, 77, 78
Invariant, 72, 73
Invariant basis, 155, 156
Invariant equation, 72
Invariant interval, 116
Isotropic coordinates, 241, 468
Israel formalism, 283, 290, 291, 309, 485

J
Jupiter, 21

K
Kaluza-Klein theory, 206, 393, 400, 404
Kasner universe, 353
Kepler motion, 240, 463, 465
Kepler's 2nd law, 235
Kepler's 3rd law, 236, 263, 484
Kerr, 275
Kerr black hole, 278, 280
Kerr metric, 275, 278
Kerr-Newman spacetime, 299, 302, 304
Kerr solution, 276
Kerr spacetime, 271, 275, 277, 280, 281, 283, 479, 481, 483
Killing equation, 154–156
Killing vectors, 154–157
Kinetic energy, 46
Klein, 404
Koszul connection coefficient, 140
Kretschmann curvature scalar, 216, 297
Kruskal–Szekeres, 216, 222, 224
Kruskal–Szekeres line element, 224

L
LAGEOS satellites, 253
Lagrange density, 204
Lagrange dynamics, 463
Lagrange equation, 128, 129, 228, 464
Lagrange equations free particle, 129
Lagrange function, 127–129, 131, 171, 206, 250, 276, 403, 463, 476
Lagrange function free particles, 129
Lagrange multiplicator, 181
Lagrangian, 206, 306
Lagrangian function, 217, 447
Lambda-Cold-Dark-Matter, 338
Laplace–Beltrami operator, 158, 167
Laplace equation, 5
Laplacian, 157, 158, 162, 170
LCDM-universe, 357, 358
Leads to an Einstein–de Sitter universe, 333
Leibowitz, 401
Leibowitz-Rosen tensor, 401
Lemaître, 200, 321
Lemaître-Friedmann-Robertson-Walker universe models, 311
Lemaître-Tolman-Bondi, 355
Length, 35
Length contraction, 33
Lense, 19
Lense-Thirring effect, 19, 250
Lever paradox, 49
Levi-Civita, 124, 295
Levi-Civita Bertotti-Robinson metric, 283
Levi-Civita Bertotti Robinson solution, 295
Levi-Civita Bertotti Robinson spacetime, 297
Levi-Civita connection, 123
Levi-Civita symbol, 80, 251
LFRW cosmological models, 330
LFRW universe, 500
LFRW universe models, 325, 348, 384, 493
Lie derivative, 155, 156
Light, 33
Light cone, 24, 218
Light cone coordinates, 223
Light deceleration of, 226
Light deflection of, 236
Light-like, 37, 39, 78
LIGO, 243, 260, 263, 269
Linear combination, 59
Linear field approximation, 243, 252
Linearized field equations, 246
Linearly independent, 59
Line element, 40, 75, 83, 93, 94, 98, 101, 104, 161
Line element free particle, 129
LIVE, 200, 210, 242, 285, 306, 311, 318, 321, 328, 336, 338, 339, 344, 345, 348, 353, 354, 357, 358, 366, 374, 386, 460, 462, 492, 497, 502
LIVE-Cold-Dark-Matter, 338
Local derivative, 151
Local inertial frame, 215
Local inertial reference frame, 135
Locally Cartesian coordinates, 192
Locally Cartesian coordinate system, 186
Lookback time, 329, 335, 383, 489
Lopez, 300
Lopez's source of the Kerr-Newman metric, 303
Lorentz contracted, 95
Lorentz contraction, 33, 35, 56, 95, 96, 108, 420
Lorentz factor, 30
Lorentz force, 252
Lorentz invariance, 200
Lorentz invariant, 37, 47, 75, 460
Lorentz invariant vacuum energy, 200, 311, 318, 338
Lorentz's force law, 52
Lorentz transformation, 34–37, 47, 58, 92, 95, 109, 423, 425, 460
Lorenz condition, 164
Lorenz gauge, 164
Lorenz gauge condition, 252, 254
Lowering an index, 74
Luminosity distance, 385
Lyth bound, 371

M
Mach, 19
Mach's principle, 18
Magnetic flux density, 163
Magnetism, 51
Manifestly covariant, 18
Mass, 44, 45
Material derivative, 151
Matrix, 81
Matter-dominated universe, 385
Mattig's formula, 385, 496
Maximally linearly independent, 59
Maximally symmetric, 155
Maxwell, 33
Maxwell's equations, 18, 51, 162, 252, 424
Maxwell source equations, 166
Maxwell's source free equations, 165, 208
Measuring rods, 97

Mechanical energy, 266
Mercury, 227, 241, 471
Mercury's orbit, 236
Mercury's perihelion precession, 233
Meson, 56
Metric, 72
  Kerr (rotating), 275
Metric covariant differentiation, 146
Metric perturbations, 257
Metric static, stationary, 129
Metric tensor, 72, 74, 81, 82, 94, 146, 200, 216, 232
Michelson and Morley, 33
Michelson interferometers, 260
Michelson–Morley experiment, 33
Milky Way, 107, 108
Milne universe, 353, 383, 388, 490, 507
Milne universe model, 319
Mini-black hole, 275
Minkowski diagram, 23, 24, 30, 42, 102, 106, 133, 388, 433
Minkowski-force, 62
Minkowski force form, 168
Minkowski line-element, 76
Minkowski metric, 76, 86, 148, 210, 243, 317, 433, 459
Minkowski space, 116
Minkowski spacetime, 75, 78, 133, 166, 214, 223, 244, 277, 295, 296, 300, 319, 320, 377, 460
Minkowski space-time from Schwarzschild solution, 214
Minkowski universe, 353
Mixed components, 86
Mixed metric tensor, 74
Mixed tensor, 70, 71
Møller coordinates, 108
Momentum, 47, 48
Momentum-energy tensor, 198
Moon, 12, 21, 413
Multilinear function, 70
Multi messenger astronomy., 269

N
Natural Inflation, 389, 508
Newton, 1, 18
Newton fluid, 198
Newtonian 3-velocity, 151
Newtonian approximation, 190, 210, 215, 459, 497
Newtonian fluid, 197, 198
Newtonian force, 16
Newtonian gravitational potential, 190, 251
Newtonian gravity, 230, 289
Newtonian hydrodynamics, 151, 198
Newtonian law of gravitation, 203
Newtonian limit, 135, 191, 203, 214, 325, 459, 470
Newtonian physics, 190
Newtonian potential, 20, 21, 203, 230, 410
Newtonian theory, 265
Newtonian tidal tensor, 191
Newton's 1st law, 16, 64, 135, 192
Newton's 2nd law, 14, 57, 412, 423
Newton's law of gravitation, 1, 4, 201, 409
Newton's law of gravity, 411
Newton's theory, 16, 95, 119, 193, 230
Newton's theory of gravitation, 1, 192
Non-Euclidean, 94
Non-tidal gravitational field, 195
Normal curvature, 181
Null-geodesic curve, 17, 359
Number of e-folds, 370

O
One-form basis, 69
Orbit equation, 231
Orthogonal basis, 82
Orthonormal basis, 64, 67, 76, 102, 104, 109, 142, 150, 160, 211, 212, 239
Orthonormal basis field, 148, 150
Outer product, 120

P
Parallel transport, 124, 174, 195, 453
Partial derivative, 122, 144
Particle horizon, 359, 379, 380, 494, 495
Particle trajectories, 228
Particle trajectory Schwarzschild 3-space, 228
Past light cone, 378
Peculiar velocity, 315
Perfect dragging, 378
Perfect fluid, 199, 210, 317, 459, 493
Perfect inertial dragging, 341, 379
Perihelion precession, 471
Perihelion precession of Mercury, 242
Perihelion shift of Mercury, 211
Permeability of empty space, 166, 207
Permeability of vacuum, 54
Permittivity of empty space, 166
P-form, 78
Phantom energy, 348, 350
Photon, 99

Photon clock, 28
Photon sphere, 242, 474
Physical components, 160
Physical laws, 18
Physical singularity, 216
Planck length, 240
Planck mass, 274, 375
Planck spectrum, 273
Planck time, 275
Plane polar coordinates, 66, 69, 73, 75, 123, 140, 150
Poincaré's lemma, 121, 158, 160, 162, 164, 165, 167, 178, 185, 395
Poisson equation, 7, 385
Polarization, 256, 257, 372
Polynomial inflation, 375
Pound-Rebka experiment, 140
Power spectra, 373
Precession, 235
Precession of Mercury's perihelion, 233
Pressure, 44
Pressure forces, 8
Primordial black hole, 275
Principal curvatures, 182
Principle of equivalence, 1, 15, 16, 95, 192, 215
Principle of general relativity, 136
Principle of relativity, 1, 17, 18, 41, 95, 380
Projectile motion, 171
Projection, 89, 153
Projection tensor, 113, 114, 153
Proper acceleration, 105, 107, 114
Proper distance, 92
Proper time, 30, 38, 78, 98, 112, 116, 127, 134, 216
Proper time-interval, 40, 106, 232
Proxima Centauri, 137

Q
Quasars, 417

R
Radar method, 25
Radially moving photons, 219
Radiation, 45, 200, 317, 321, 328
Radiation dominated universe, 330, 361, 384, 496
Radiation-dominated universe model, 330
Radiation pressure, 44
Rank, 70, 71
Rapidity, 36, 109, 110
Redshift, 56
  Kerr spacetime, 276
Redshift cosmological, 315
Redshift–luminosity relation, 385, 496
Reduced mass, 263
Reference frame, 16, 17, 64
Reference frame inertial, 123
Reference particle, 94
Reinterpretation principle, 50
Reissner-Nordström solution, 211, 239, 406
Reissner-Nordström spacetime, 238
Relativistic Doppler effect, 67, 421
Relativistic Doppler shift, 56
Relativistic gravitational potential, 325
Relativistic gravity, 230
Relativistic rotating disc, 115, 429
Relativity of simultaneity, 30, 32, 50, 92, 93, 96
Repulsive gravitation, 285, 321
Rest acceleration, 42, 43
Rest frame, 61
Rest length, 33
Ricci
  curvature, 177
  identity, 184
    component form, 184
Ricci curvature scalar, 177, 179, 207, 213, 243
Ricci curvature tensor, 177, 179, 213, 243, 457
Ricci curvature tensor, divergence, 201
Ricci identity, 184
Ricci scalar, 244
Ricci tensor, 201
Riemann curvature forms, 179
Riemann curvature tensor, 173, 175–178, 184, 186, 190, 195, 213, 243, 457
Riemannian space, 188
Riemann tensor, 175–177, 179, 184, 189, 255
Rigid rotation, 104
Rindler coordinates, 108
River model of space, 283
River of space, 306
Robb, 54
Robb's formula, 417
Robertson–Walker line element, 314
Robertson–Walker metric, 312, 359
Robertson–Walker universe, 383
Roche limit, 21, 416, 417
Rosen, 401
Rosser, 47
Rotating black hole, 275
Rotating frame, 94–96, 101, 102, 141

Rotating frame of reference, 170, 447
Rotating motion, 95
Rotating reference frame, 92, 99, 101, 195, 447, 456
Rotating reference frame connection coefficients, 140
Rotating spherical shell, 247
Rotation, 152, 153
Rotational motion, 380
Running of the spectral indices, 373

S
Sagnac effect, 99, 280
Sagnac experiment, 89
Scalar field, 318, 444
Scalar perturbation, 372
Scalar product, 72
Scalar quantity, 70
Scale factor, 311, 317, 379
Scale invariant, 373
Schwarzchild spacetime, 223, 272
Schwarzschild 3-space, 228
Schwarzschild 3-space energy, 228
Schwarzschild 3-space momentum, 228
Schwarzschild black hole, 273, 279, 476
Schwarzschild-de Sitter metric, 241, 309, 469, 484
Schwarzschild-de Sitter spacetime, 306, 485
Schwarzschild horizon, 241, 308
Schwarzschild light cones, 218
Schwarzschild line-element, 223, 475, 487
Schwarzschild metric, 215, 216, 225, 239, 241, 293
Schwarzschild metric embedding, 225
Schwarzschild radius, 3, 19, 216, 218, 222, 226, 227, 236, 238, 243, 264, 268, 271, 278, 279, 293, 299, 378–382, 469, 474, 486, 488
Schwarzschild's exterior solution, 211
Schwarzschild's interior solution, 287
Schwarzschild solution, 211, 241, 468, 469
Schwarzschild space, 241
Schwarzschild spacetime, 211, 216–218, 225, 238, 247, 250, 272, 468, 479, 481, 487
Semi-latus rectum, 266
Shapiro, 226
Shapiro experiment, 226
Shear, 152, 153
Shoemaker-Levy, 21
Shoemaker-Levy 9, 417
Simultaneity, 101
Simultaneity space, 91, 102, 104, 115, 153
Simultaneous events, 93
Singularity coordinate, 216
Singularity physical, 216
Singular mass shells, 290
Slow roll approximation, 367
Slow roll era, 374
Slow roll parameters, 368, 375
Space, 42
Space-like, 37, 78
Space ship, 117
Spacetime, 16, 61, 64, 65, 247
Spacetime curvature, 17, 190
Spacetime interval, 37
Spatial geodesics, 447
Spatial geometry, 89, 95
Spatial line-element, 90, 94, 114
Spatial metric, 102, 114
Spatial metric tensor, 89, 91, 94, 114
Spatial simultaneity space, 456
Special principle of relativity, 17
Special theory of relativity, 23, 25, 41, 98, 200
Spectral indices, 373
Spectral parameters, 509
Spectral tilt, 375
Spherical coordinates, 161, 169, 214, 247, 444
Spherical coordinate system, 82
Spherically symmetric spacetime, 209
Spontaneous symmetry breaking, 361, 362
Standard clock, 98, 112, 116, 134, 217
Standard measuring rod, 95, 96
Static border, 278
Static metric, 129, 275
Stationary metric, 129, 275
Stefan–Boltzmann law, 274, 330, 364
Structure coefficients, 68, 143, 148, 176, 188
Sun, 226, 227, 236, 238, 264, 269, 274
Surface curvature, 183
Surface gravity, 271, 273
Synchronization, 25

T
Tachyons, 50
Tachyon telephone paradox, 51
Tangent vector, 66
Tangent vector field, 62, 64, 125
Taylor expansion, 193
Tensor, 59, 69, 78, 146
  contraction of, 177
  Ricci curvature, 177

  Riemann curvature, 175
Tensor covariant differentiation of, 146
Tensor Einstein, 202
Tensor equation, 18, 72
Tensor momentum energy, 198
Tensor perturbation, 373
Tensor product, 70, 86, 426
Tensor Riemann curvature, 213
Tensor-to-scalar ratio, 373
Tetrad, 102
The de Sitter universe models, 336
The Friedmann–Lemaître model, 337
The Hubble parameter, 503
Theorema egregium, 184
Theory of relativity, 95
The river of space, 305
The static border, 278
The twin paradox, 54, 417
Thin dust shell, 291
Thirring, 19, 377
Tidal acceleration, 190
Tidal field, 14
Tidal force, 1, 10, 16, 173, 193
  pendulum
    relativistic, 196
Tidal force pendulum, 19, 196, 409, 410, 458
Tidal gravitational field, 194
Tidal potential, 14
Tilt, 373
Time dilation, 28, 30, 38, 39, 56, 98, 134, 420
Time-like, 37, 76
Tolman–Oppenheimer–Volkoff (TOV) equation, 285, 287, 288
Tolman–Whittaker expression, 284
Tolman-Whittaker formula, 299
Torque, 49
Torsion, 187
Torsion form, 187
Total derivative, 151, 153
Transformation matrix, 81
Transverse traceless gauge condition, 256
Twin paradox, 40, 41, 136, 138

U
Uniformly accelerated motion, 42, 43, 114
Uniformly accelerated reference frame, 43, 89, 105, 107, 112, 116, 131, 139, 171, 449
Uniformly accelerated space ship, 436
Uniformly accelerated system of reference, 433
Unit vector, 67
Universe, 19
Universe model dust dominated, 331
Universe model inflationary, 363
Universe model radiation dominated, 330

V
Vacuum energy, 200
Vacuum field equations, 204
Variational principle, 130, 131, 204, 206
Vector, 18, 59
Vector field, 64
Vectorial form, 147
Vector perturbation, 372
Velocity, 47
Velocity addition, 36
Velocity field, 151
4-velocity identity, 129
Velocity of light, 24
Venus, 226
Vertical free fall, 131
Vertical projectile motion, 451
Virgo, 263, 269
Volume-element, 82
Volume expansion, 152
Volume form, 80, 82, 83
Vorticity, 372

W
Wave number, 373
Weak gravitational field, 216
Wedge product, 79, 84
Weingarten's equation, 181
Wheeler, 204
White hole, 221
Wien's displacement law, 273
World line, 24, 38, 42, 76

Z
Zel'dovich fluid, 366
Zero-Angular-Momentum-Observers (ZAMO), 250, 276, 277, 280, 377, 480