

# Index

- accretion torus, 177
- action
  - of a free particle, 47
  - of general relativity, 86
- adapted coordinates, 115
- algebra, 70
- alternation operator, 69
- atlas, 15
  - differentiable, 16
- Bianchi identities
  - contracted, 45
  - first and second, 40
  - for Riemannian connection, 44
- Birkhoff's theorem, 125
  - generalised, 186
- Cartan's equation, 72
- Cartan's structure equations, 113
- chart, 15
- chirp mass, 108
- Christoffel symbols, 32
  - for linearised gravity, 91
  - of Riemannian connection, 43
  - transformation, 33
- codifferential, 74
  - coordinate expression, 74
- cofactor, 54
- commutator, 24
- connection
  - affine, 32
  - linear, 32
  - metric, 42
  - Riemannian or Levi-Civita, 42
    - symmetric, 33
- connection forms, 111
- contraction, 26
- convergence, 202
- cosmological constant, 84
- and energy-momentum tensor, 89
- covariant derivative, 33
  - of a dual vector, 36
  - of a tensor, 38
- covariant differentiation, 32
- Cramer's rule, 54, 85
- curvature, 39
  - and tidal field, 81
- curvature tensor, 40
  - in arbitrary basis, 114
  - symmetries, 44
- curve, 23
- derivation, 20
- diffeomorphism
  - invariance, 93
  - one-parameter group, 23, 63
- differential forms, 69
  - exact and closed, 72
- differential of a function, 24
- Doppler shift, 8
  - and redshift, 54
- dual vector, 24
- Eddington-Finkelstein coordinates, 154
- eikonal equation, 52
- Einstein
  - elevator, 7
  - field equations, 83
    - linearised in Hilbert gauge, 94
    - tensor, 45
  - equivalence principle
    - Einstein's, 5
    - weak, 5
- energy non-conservation, 58
- energy-momentum tensor, 88
  - of electromagnetic field, 88

- exponential map, 35
- exterior derivative, 71
  - coordinate expression, 72
- exterior product, 70
- Faraday 2-form, 75
- Fermat's principle, 96
- frames
  - freely-falling, 7
  - inertial, 6
- Friedmann's equations, 193
- Frobenius condition, 116
- gauge invariance, 93
- Gauss' theorem, 76
- generator of a transformation, 23
- geodesic, 34
  - and free fall, 48
  - and light rays, 53
  - congruence, 77
  - deviation, 80
  - equation, 34
    - in Newtonian limit, 58
- geometrical optics, 51
  - change of amplitude, 53
  - polarisation transport, 51
- Gibbons-Hawking-York boundary term, 86
- Grassmann algebra, 71
- Grassmann identity, 101
- gravitational wave
  - equation, 100
  - polarisation tensor, 102, 103
- gravitomagnetic field, 98
  - equation of motion in, 99
  - Lense-Thirring effect, 99
- Gravity Probe B, 100
- Hilbert gauge, 94
- Hilbert-Palatini action, 89
- Hodge \* operator, 73
- index of refraction in weak gravitational field, 96
- inhomogeneous wave equation for electromagnetic field, 51
- innermost stable circular orbit, 133
- integration of an  $n$ -form, 75
- interior product, 71
- ISCO, 133
- isometry, 65
- Jacobi equation, 79
- Jacobian matrix, 22
- Kerr spacetime
  - angular velocity, 169
  - ergosphere, 171
  - Kepler's third law, 172
  - Killing horizon, 171
  - redshift near static limit, 170
  - static limit, 169
- Kerr(-Newman) solution, 166
  - gyromagnetic moment, 167
  - radial magnetic field, 167
- Killing
  - equation, 68
  - vector field, 68
  - vector fields and conservation laws, 69
- Koszul formula, 42
- Kruskal(-Szekeres)
  - continuation, 151
  - coordinates, 151
- Laplace expansion, 55
- Lense-Thirring effect, 99
- Lie derivative, 65
  - and commutator, 66
  - coordinate expressions, 67
- Lie transport, 78
- light deflection, 9
  - by the universe, 205
  - in Newtonian limit, 59
- light speed in weak gravitational field, 96
- Lorentz force, 50
- Lorentzian spacetime, 28
- Lovelock's theorem, 84
- manifold, 15
  - differentiable, 16
- Maxwell's equations
  - in general relativity, 50
  - in special relativity, 49
- metric

- (pseudo-)Riemannian, 28
- Friedmann-Lemaître-Robertson-Walker, 194, 198
- Kerr(-Newman), 166
- of static spacetime, 116
- Reissner-Nordström, 162
- Schwarzschild, 122
- tensor, 27
- neutron stars
  - mass limit, 210
- optical tidal matrix, 202
- Palatini identity, 85
- parallel transport, 34
- Penrose-Carter diagram, 152, 227
- perihelion shift
  - in scalar theory of gravity, 13
  - in Schwarzschild spacetime, 135
- Planck
  - temperature, 181
  - units, 4
- polarisation
  - and parallel transport, 53
  - tensor, 102
- product manifolds, 18
- pull-back, 64
- push-forward, 64
- quadrupole
  - formula, 106
  - tensor, 105
- redshift
  - cosmological, 197
  - gravitational, 8, 10
  - near Schwarzschild radius, 159
- Reissner-Nordström solution, 162
- Ricci
  - identity, 42
  - scalar, 45
  - for linearised gravity, 92
  - tensor, 40
  - for linearised gravity, 92
- Riemann tensor, 40
- Robertson-Walker metric, 191, 198
- scalar product, 27
- Schwarzschild solution, 122
- Schwarzschild spacetime
  - Eddington-Finkelstein coordinates, 154
  - effective potential, 129
  - equation of motion in, 130
  - Kruskal(-Szekeres) continuation, 151
  - Lagrangian of, 127
  - last stable orbit, 133
  - light deflection, 137
  - perihelion shift, 135
  - spin precession, 140
- Schwarzschild tetrad, 118
- curvature forms of, 120
- Einstein tensor of, 121
- Ricci scalar of, 121
- Ricci tensor of, 120
- Shapiro delay, 97
- shear
  - components, 202
  - matrix, 202
- simultaneous events, 6
- spacetimes with constant curvature
  - metric, 190
  - Ricci scalar, 189
  - Ricci tensor, 189
- spatially homogeneous spacetime, 188
- spatially isotropic spacetime, 188
- spherically symmetric spacetime, 183
  - connection forms, 185
  - curvature forms, 185
  - Einstein tensor, 186
  - Ricci scalar, 185
  - Ricci tensor, 185
- static spacetime, 116
- stationary spacetime, 115
  - axially symmetric, 164
- Stokes' theorem, 76
- structure equations, Cartan's, 113
- tangent space, 20
  - basis, 22
- tensor, 25
  - transformation of, 26

- tensor field, 25
- Tolman-Oppenheimer-Volkoff equation, 208
- torsion, 38
  - forms, 112
  - tensor, 39
    - in arbitrary basis, 114
- two-sphere, 16
  - atlas, 16
- variational principle of general relativity, 86, 89
- vector field, 22
  - flow of, 63
  - global flow of, 63
  - integral curve of, 63
  - parallel, 34
- vector space, 19
- vectors and infinitesimal transformations, 23
- volume form, 73
  - canonical, 73
- weakness of gravity, 4
- Weyl tensor, 200