

Index

- action, 119
- algebra of charges, 203
- angular type fields, 193
- angle type variable, 196
- anomaly, 212
- anomaly constraint, 248
- anomalous dimension, 219, 222, 225
- anomalous magnetic moment of W bosons, 199
- anti De Sitter, 434
- asymptotic freedom, 217, 223
 - and fixed points, 223
 - in QCD, 225
- atlas, 119
- axial vector anomaly, 212

- back reaction, 368
- baryon
 - asymmetry, 243, 274
 - conservation violation, 240
 - number, 169, 197
- beauty, 210
- beta decay, 208
- Bianchi identity, 24, 91, 92, 125, 459, 471
- Birkhoff's theorem, 32
- Bjorken scaling, 180, 216
- black holes
 - area theorem, 44
 - collapse, 400
 - entropy, 45
 - ergosphere, 40
 - event horizon, 39
 - angular velocity, 44
 - electric potential, 44
 - surface gravity, 44
 - Hawking effect, 47, 48, 323
 - infinite redshift surface, 34, 39
 - irreducible mass, 44, 45
 - Kerr, 28
 - Kerr–Newman, 41, 43
 - no hair theorem, 43
 - null surface, 35, 39
 - one way membrane, 35, 39
 - Penrose process, 40, 45
 - Reissner–Nordstrom, 41
 - Schwarzschild, 31
 - stability, 41
 - static limit, 33
 - stationary limit, 38
 - superradiance, 46
 - temperature, 47
 - thermodynamics, 45, 46
 - uniqueness, 41
 - Zeldovich–Starobinsky–Unruh effect, 47
- bottom, 216
- Brans–Dicke scalar, 429

- Cabibbo
 - angle, 200
 - Kobayashi–Maskawa matrix, 233
 - rotated quark, 201, 209
 - rotation in two dimensions, 209
 - universality, 200
- Callan–Symanzik equation, 219
- canonical
 - dimension, 221, 224
 - momentum, 136
 - number of representation, 196
 - quantization, 138, 298
- Cartan
 - differential algebra, 122
 - Killing form, 485
- Casimir effect, 318, 319
- causal boundary, 113
- causality, 108
- charged currents, 207
- charge conjugation, 143
- C-violation, 176
- CP-violation, 177, 299
- CPT theorem, 178, 200
- charge independence of nuclear forces, 166
- chart, 119
- chemical potential, 62
- Chern
 - class, 286
 - form, 286
 - Simons, 518

- chiral supermultiplet, 496
- Christoffel symbols, 18
- classical field theory, 135
- classification of singularities, 278, 280
- Clifford algebra, 420
- clock field, 377
- closed timelike lines, 102
- closure density, 58
- Coleman–Mandula theorem, 489
- Coleman–Weinberg, 343
- colour, 180, 215
 - confinement, 228, 229
- compact space, 423
- compactification, 91
 - conformal, 113
 - Freund–Rubin, 434
 - monopole, 436
- complex doublet of scalars, 191
- complex Klein–Gordon field, 137, 186
- conformal
 - compactification, 113
 - degree of freedom, 375
 - transformation, 305
- connection
 - affine, 475
 - spin, 473
- conserved current, 212
- constraint equation, 382, 402
- Cooper pairs, 214
- coordinate systems
 - advanced null, 115
 - Boyer–Lindquist, 37
 - comoving, 52
 - locally inertial, 21
 - natural, 21
 - retarded null, 115
- Copernican principle, 51
- coset spaces, 442
- cosmological constant, 53, 399
- cosmological models
 - anisotropic
 - Bianchi type V, 104
 - Bianchi type IX, 104
 - Big Bang, 59
 - closed elliptic, 54
 - De Sitter, 55, 348, 351
 - dust, 53
 - Einstein–De Sitter, 54
 - Einstein static, 55
 - Friedmann–Robertson–Walker, 52, 53, 343, 376
 - Gödel, 101
 - inflationary, 343, 348, 390
 - Kasner, 458
 - open hyperbolic, 54
 - radiation, 54
 - steady state, 55
 - cosmological principle, 53
 - cosmological redshift, 56
 - cosmogenesis, 390
 - creation of the universe, 390
 - critical temperature, 213
 - cubic vertices, 192
 - Curl, 123
 - current algebra, 201
 - current-current form, 200
 - deceleration parameter, 57
 - deep inelastic scattering, 216
 - density perturbations, 352
 - derivative
 - coupling, 211
 - covariant, 15, 16
 - covariant exterior, 124
 - gauge covariant, 186, 201, 257, 471
 - Lorentz covariant, 417
 - operator, 111
 - Poincaré covariant, 478
 - SL (2, C) covariant, 473
 - diffeomorphism, 108, 109
 - dimensional reduction, 423, 454, 455, 514
 - dimensional regularization, 157, 178
 - Dirac field, 137
 - Dirac's large number hypothesis, 461
 - distribution functions, 62
 - divergence, 123
 - divergences
 - degree of, 211
 - in QED, 153
 - duality, 524
 - dynamical dimension, 222
 - eightfold way, 180
 - Einstein
 - Cartan equation, 131
 - theory, 126, 131, 468
 - field equation, 26
 - Hilbert Lagrangian, 407, 455
 - spaces, 434
 - summation convention, 8
 - thought experiment, 3
 - electromagnetic field, 138, 187
 - electroweak model, 198, 203
 - see also* Glashow–Salam–Weinberg
 - consequences, 206
 - effective coupling constant, 228

- endomorphism, 483
- entropy problem, 464
- expansion, 94
- explicit mass term, 212
- extrinsic curvature, 401

- Faddeev–Popov, 225
- Fermi
 - contact interaction, 207
 - coupling constant, 207
 - theory, 211, 212
- fermion masses, 266, 205
- fermionic mass term, 204
- Feynman graphs, 150, 152, 211
- Feynman–Gell–Mann, 200
- flatness problem, 83, 346
- flavours, 210
- FCCC weak interactions, 233
- Fock space, 140
- forms
 - connection, 123
 - curvature, 123
 - differential, 119
- Freund–Rubin compactification, 434
- functional Schrödinger equation, 401

- galaxy formation, 84
- Gamow, 59
- gauge
 - Fock–De Donder, 408
 - Landau, 225
 - light cone, 529
 - Lorentz, 405
- gauge field, 187
 - non-Abelian, 192
- gauge hierarchy problem, 235, 487
- gauge potential, 471
 - translational, 478
- gauge theory, 467
 - of gravity, 126
- gauge transformation, 187, 407, 467
 - global, 186, 187
 - local, 187
 - rigid, 187
- gauge invariance, 142
 - local, 182, 449
- Gell–Mann–Nishijima formula, 169
- generations, 213
- general coordinate transformations, 473
- general invariance, 193, 212
- general mass matrix, 196
- general SU(2) transformations, 191, 193
- general U(1) transformations, 187

- Geometry
 - Euclidean, 4
 - fundamental tensor, 12
 - geodesics, 5, 20
 - gravitation, 5
 - line element, 6
 - Lobachevsky, 5
 - parallel postulate, 4
 - Riemannian, 5
- generalized Wheeler–De Witt equation, 382
- generation puzzle, 234
- ghosts, 225
- Glashow–Iliopoulos–Maini(GIM), 209, 234
- Glashow–Salam–Weinberg, 184, 198, 203
 - see also* electroweak
- gluon, 215, 227
 - radiation, 230
- goldstino, 503
- Goldstone
 - fields, 431
 - Higgs Lagrangian, 213
 - model, 187
 - theorem, 189
- graded lie algebra (GLA)
 - Abelian, 485
 - nilpotent, 485
 - semisimple, 485
 - simple, 485
 - solvable, 485
- gradient, 122
- grand unification, 235, 237, 247
- Grassmann algebra, 121
- gravitino, 410
- graviton, 407
- groups
 - Abelian, 191
 - adjoint representation, 289
 - Casimir operators, 291
 - commutation relations, 288
 - colour, 214
 - complex UIR, 291
 - compact Lie, 288
 - exceptional, 289
 - fundamental homotopy, 283
 - fundamental UIR, 290
 - isometry, 439
 - Lie bracket, 288
 - local Lie, 288
 - orbits, 93
 - potentially real representations, 291
 - pseudo real representations, 291
 - rank, 289
 - representation

- adjoint, 484
- completely reducible, 484
- reducible, 484
- semisimple Lie, 288
- simple Lie, 288
- structure constants, 92, 288, 468, 215
- topological, 288
- universal covering, 288
- Gupta, 407
- harmonic analysis, 429, 441
- harmonic functions, 423
- Hamiltonian, 137
- Hamidew coefficients, 366
- helium synthesis, 72
- Higgs
 - field, 204
 - mechanism, 191
 - model, 190
 - potential, 263
- high-temperature approximation, 210, 212
- higher-order loop diagrams, 210, 212
- homogeneous, 52, 84
- horizontal lift basis, 424
- horizon problem, 83, 90, 345
- Hubble constant, 56
- hydrogen atom, 384
- ideal, 485
- ideal gas, 61
- ideal point boundary, 114
- indecomposable past set, 114
- induced gravity, 235
- inflation
 - chaotic, 354
 - limits on models, 355
 - primordial, 392
- interactions, 164
- interacting fields, 145
- interaction picture, 146
- internal symmetry, 440
- invariance under general transformation, 210
- infrared
 - divergences, 227
 - fixed point, 223
 - problem, 228, 229
- jets, 231
- Kaluza–Klein theory, 423, 450, 235
 - Chiral fermions 444
 - cosmology, 456, 457, 462
 - ground state, 427, 433
 - old, 424
 - modern, 427
 - zero modes, 429
- Killing vector, 33, 34, 91, 110, 111, 439
- Lagrangian, 135
- Landau–Ginzburg, 213
- left-handed fields, 202
- length-type fields, 193
- lepton
 - conservation violation, 240
 - deep inelastic scattering, 216
 - doublet, 210
 - electromagnetic, weak interaction of, 200
 - gauge boson interaction, 206
 - masses, 206
 - number, 171
 - tau, 210
- Lichernowicz theorem, 445
- Lie algebra, 288
- local translations, 479
- London penetration length, 214
- Lorentz invariance, 134
- low-temperature approximation, 63
- lowering, 13
- Mach principle, 102
- Majorana conditions, 421
- manifest relativistic invariance, 473
- manifold, 107, 119
- mass matrix, 233
- massive vector boson, 191, 194, 211
 - charged, 198, 199, 212
 - neutral, 198, 212
 - propogator, 211
- massless
 - gauge boson, 196
 - particle, 189
 - vector boson, 191
- matter spin density, 477
- measurement process, 395
- Meissner effect, 214
- microwave background, 60, 75, 343
 - see also* relic radiation
 - anisotropies, 78, 344
- minimal electromagnetic coupling, 199
- minimal SU(5), 247, 250, 258, 267
- minisuperspace, 374
- mixing angle, 208
- momentum dependent coupling constant, 217, 222
- monopoles, 279, 280
- monopole compactification, 436
- monopole problem, 84, 347

- moving coordinates, 221, 222
- moving coupling constant, 222
- naked singularity, 40
- Nambu–Goldstone boson, 189
- Nambu–Goto action, 527
- naturalness, 487
- natural units, 164
- neutrinos
 - massive, 89
 - oscillations, 234
 - primordial, 65
 - scattering
 - coherent, 208
 - elastic, 208
 - temperature, 69
- Noether current, 181
- Noether theorem, 469
- nonrenormalizable theories, 210
- nonrelativistic potential scattering, 217
- normal ordering, 141
- null infinity, 114
- order parameter, 214
- paracompact, 119
- parity, 143, 172
 - violation, 174
- participatory observer, 383
- parton, 216, 230
- Pauli–Fierz Lagrangian, 431
- Peccei–Quinn symmetry, 279
- perfect cosmological principle, 55
- perfect fluid, 26, 53
- phase transition, 277, 337, 213
- photon, 405, 407
- photon to baryon ratio, 77
- photon temperature, 69
- Planck dimensions, 297, 394
- points at infinity, 113
- point splitting, 368
- polarization
 - vectors, 406
 - tensors, 409
- preons, 235
- primordial
 - inflation 354, 394
 - magnetic fields, 90
 - nucleosynthesis, 61, 73
- proton decay, 272
- proton antiproton collider, 208
- QCD, 214
- QED, 183, 211
- QFD, 231
- quantum cosmology, 374
- quantum gravity, 373
- quantum stationary states, 388
- QFT in CST
 - adiabatic vacuum, 312
 - canonical quantization, 298
 - conformal
 - anomalies, 333
 - coupling, 301
 - vacuum, 306
 - De Witt–Schwinger expansion, 361
 - divergences, 299, 397
 - effective action, 363, 397
 - Green function, 397
 - history, 344
 - minimal coupling, 301
 - path integral formulation, 321
 - renormalization, 365
 - scalar field, 300
 - vacuum energy, 320
- Quark, 214
 - antiquark bound states, 209
 - charmed, 209
 - EM, weak interaction, 200
 - gauge boson interaction, 206
 - lepton universality, 235
 - masses, 206
 - strange, 205, 209
- quartic vertices, 192
- raising, 13
- Rarita–Schwinger field, 411, 509
- Recombination, 77
- real triplet scalar field, 194
- relativity
 - general, 4
 - special, 3
- relic radiation, 60
- regular point, 114
- renormalization, 153
- renormalizability
 - criterion, 211
 - of non-Abelian theory, 212
 - of weak interaction, 212
- renormalized coupling constant, 219, 220
- renormalization group, 217, 218, 220
- renormalizable theories, 220
- reparametrization invariance, 381
- Riemann's zeta function, 315
- right-handed fields, 202
- right-handed neutrino, 202

- rotation, 94
- Rutherford scattering, 216
- scalar curvature, 25
- scaling, 230
- S-matrix, 151
- self coupling, 211
- self energy, 153
- self interacting, 192
- semiclassical cosmology, 388
- shear, 94
- spacetimes
 - anisotropic, 99–105
 - asymptotically flat, 114
 - axially symmetric, 37
 - causal boundary of, 113
 - conformal compactification of, 113
 - Kerr, 28
 - Lense–Thirring, 38
 - Robertson–Walker, 28
 - Schwarzschild, 31
 - static, 32
 - stationary, 37
- spacetime dependent phase transformations, 187
- special U(1) transformation, 187
- special SU(2) transformation, 191, 193
- SU(2)
 - gauge theory, 191
 - triplet vector representation, 194
- SU(2) × U(1)
 - charges of fermions, 201
 - general invariance, 210
 - model, 196
- SL(2, C) gauge field strength, 475
- spinors, 420
- spontaneous symmetry breaking, 187, 189, 260
 - of discrete symmetry, 189
 - SU(2), 193
 - nonabelian, 195
- spontaneous compactification, 454
- stable causality, 108
- standard model before gauge theories, 199
- standard gauge model of particle physics, 185, 231, 232, 247
- strangeness, 169
 - changing decay, 200
 - changing neutral current, 209
- strings
 - closed, 533
 - cosmic, 279
 - field theory limit, 534
 - free relativistic, 526
 - heterotic, 538
 - interacting, 533
 - light cone quantization, 528
 - Lorentz covariance, 531
 - spectrum, 532
 - superstrings, 235
 - subalgebra, 485
- Sudarshan–Marshak, 200
- superconducting state, 214
- supergravity, 508
- supernova, 208
- supersymmetry, 487
 - algebra, 489
 - gauge theory, 501
 - mass formula, 506
 - representation, 492
 - spontaneous breakdown of, 502
- tachyons, 188
- technicolour, 488
- tensor, 11
 - contorsion, 419
 - curvature, 21, 23, 24, 113, 475
 - Einstein, 25
 - energy momentum, 26, 53
 - field strength, 470
 - Lie derivative of, 111
 - metric, 12
 - quotient law for, 11
 - Reimann, 113
 - see also* curvature
 - Ricci, 25
 - torsion, 468, 475
- tetrad, 415
 - see also* vierbein
- thermodynamic equilibrium, 61
- Thomson model, 216
- time reversal, 144
- T-invariance, 144, 176
- topological currents, 282
- toponium, 230
- truth, 210
- ultraviolet
 - cutoff, 220, 397
 - divergence, 210
 - fixed point, 223
 - unification scale, 235
- U(1) gauge theory, 185
- vacuum expectation value, 190
- vacuum polarization, 153

- vector
 - addition, 14
 - contravariant, 9
 - covariant, 10
 - covariant derivative, 15, 16
 - field, 110
 - parallel transport, 16
 - potential for EM, 187
- Veneziano, 526
- vertex, 153
- vorticity, 96
- vierbein, vielbein, 410, 415, 420, 468, 474
 - see also* tetrad
- V-A, 200
- very early universe, 82, 214
 - quantum effects, 360
- W-boson, 208
- weak interaction, 200
 - FCCC, 233
 - interaction strength, 208
 - hypercharge, 202
 - isospin, 202
 - mixing angle, 198
- Weinberg angle, 267
- Wess–Zumino supermultiplet, 497
- Weyl condition, 421
- Wheeler–De Witt equation, 379
- Witten’s model, 444

- Yang–Mills, 193, 439, 440
 - potentials for $SL(2, C)$, 474
- Yukawa couplings, 206, 211, 233
- Yukawa terms, 204

- zero point length, 394, 396
- zeta function regularization, 315, 368
- Z-boson mass, 208