

Index

Boldface numbers indicate locations of definitions, italic numbers indicate locations of lexicon entries

- 4-momentum, 38, **93**
transfer, 209, 215, 219, 300, 499
- abelian, 493
Abraham, 123, 133
Abraham–Lorentz model, 123, 132, 312
accelerator, 39
aether, 312
Aharonov, 189
Aharonov–Bohm effect, 190
Akama, 430
Akulov, 365
algebra, 493
of a Lie group, **454**
 α -particle, 39
Alvarez-Gaumé, 401, 405
Ampère, 7, 172, 182, 294, 428
amplitude, 19, 52, **113**, 116, 119, 147, 187, 193, 195, 199, 205, 232, 236, 241, 268, 271, 280, 376, 411, 475, 494
Veneziano, **398**
analytic function, 494
Anderson, 51, 52, 57, 252
annihilation
electron–positron pair, **203**
real, 137
virtual, 137
anomaly, xiii, **270**, 271, 494
Adler–Bell–Jackiw, 271
cancellation, 272, 494
characteristic, **271**
conservation, **271**, 494
gravity, 401
Green–Schwarz mechanism, 401
magnetic moment, 551
anti-electron, \bar{e} positron
antiparticle, 38, 51, 52
antiquark, 232
Appelquist, 154
Aristarchus, 4
Ashtekar variable, 407
asymptotic
freedom, 64, **246**
improvement of science, 12
states, **398**
- atom,
 $\bar{\psi}\psi$ Bohr, model of the atom, $\bar{\psi}\psi$ hydrogen atom auxiliary field, 494
- Banks, 31, 403
Bardeen, 61, 160, 252
baryon, 56, **58**, 70, 127, 157, 494
 conserved number, **76**
 magnetic moment, 161
 mass, 160
Batalin, 494, 495
Becchi, 232, 494
Berezin integration, **381**
Bethe, 51
BFV-quantization, $\bar{\psi}\psi$ quantization, BFV
Bhabha, 199
Bianchi, 185, 192, 227, 326
bijection, 494
Birkhoff, 333
Bjorken, 61, 63
 scaling, 219
BKS model, 48
black box, 6, 25
black hole, **333**
 as an elementary particle, **340**
 charged, **337**
 extremal, 403
 evaporation, **340**
 horizon, **335**
 spinning, **337**
 spinning and charged, **338**
blow-up, 434
blowing up a singularity, 339
Bogolyubov, 61
Bohm, 189
Bohr, xi, 48, 54, 447
 model of the atom, 12, 20, 45, 129, 310
Born, 48
Bose, 357
Bose condensation, 494
boson, 494
bottomonium, 154
bound state, 38
brane, 403
 Dp -, 403

- p*-, 430
 electric, 441
 magnetic, 441
 world, 433
- de Broglie, 29, 30, 48
 brook, xi
 Brout, 252
 Brout–Englert effect, \square Higgs, effect
 BRST
 quantization, \square quantization, BRST
 symmetry, 232, 243, 495
- Butler, 57
 BV-quantization, \square quantization, BV
- C*-eigenstate, 141
C-symmetry, \square conjugation, charge
C-violation, \square violation, *C*-symmetry
 Cabibbo, 65, 267
 Calabi, 402, 424–430, 438, 443, 496
 Calabi–Yau space, 402
 Callan–Gross relation, 219
 Candelas, 402, 424
 canonical quantization, 495,
 \square quantization, canonical
 caricature, \square black box, 38, 436, 437, 445
 Carus, 43
 Caswell, 64
 Cauchy sequence, 495
 Cavendish, 38
 center of mass system, \square system, CM
 CERN, 67
 Chadwick, 46, 54
 chamber
 bubble, 41
 cloud, 41
 proportional, 42
 spark, 42
- charge
 color, 75, 160, 225, 229, 229
 conjugation, 138
 Dirac quantization, 187, 189
 electric, 74
 electromagnetic, rationalized, 17
 electron, 44
 eta, 57
 flavor, 62, 62
 general, 226
 hypercharge, 62
 isospin, 146
 magnetic, 182
 operator, color, 225
 operator, electric, 171
 operator, general, 226
 quark, 61, 214
 renormalized, 209
 strangeness, 57
 violation, 65
 strong, \square charge, color
 weak isospin, 275
 charmonium, 154
 Cherenkov, 41
 Chern, 247
- Chew, 398, 399
 chirality, 177, 267, 495
 Christoffel, 343
 symbol, 323
 CKM matrix, 65, 66, 77, 144, 279, 280, 289, 300, 301, 526
 Clebsch–Gordan coefficients, 147, 150
 Clifford, 174
 Clifford algebra, 174
 closed time-like curve, 346, 347
 cloud, xi
 CM system, 101
 codimension, 496
 codomain, 496
 cokernel, 496
 Coleman, 252, 369
 Coleman–Mandula, 370
 Coleman–Weinberg effect, 252
 collider, 39
 collision, 28, \square scattering
 head-on, 101
 sticking, 95
 color, 160, 223, 224, 367, 496
 Bardeen–Fritzsch–Gell–Man ($SU(3)_c$) model, 61
 experimental proof, 214
 Han–Nambu model, 61
 theoretical confirmation, 272
 color factor, 235, 236, 240, 241
 commutator, 454
 compact space, 496
 compactification, 402, 496
 Calabi–Yau, 402
 Kaluza–Klein, 402
 completeness (of spacetime)
 b-, 336
 coordinate, 349
 geodesic, 336, 500
 metric, 336
 complex conjugation, \square conjugation, complex
 complex structure, 497
 component fields, 379
 Compton, 47
 effect, 47, 53
 wavelength, 47, 313, 527
 condensation, 196
 confinement, 64
 conjugation, 497
 charge, 138
 complex, 497
 Dirac, 176, 497
 Hermitian, 138, 236, 360, 497, 506
- conservation
 4-momentum, 38, 47, 49, 53, 73, 95–99, 103, 116, 122,
 195, 202, 233, 270
 angular momentum, 73, 95, 173
 anomaly, 271, 274, 494
 baryon number, 56, 76
 color, 75, 228, 229, 237, 242
 electric charge, 74, 173, 184, 228, 272
 energy, 47, 53–55, 73, 95, 96, 140, 173, 202, 269
 fermion number, 306
 flavor, \square flavor, conservation

- isospin, 50, 145, 147, 149
 - approximate, 153
- law, 70, 73, \square Noether, theorem
 - approximate, 76
 - strict, 73
- lepton number, 55
 - lepton numbers (separate), 56, 75, 76
- linear momentum, 47, 53, 73, 95, 173
- logical consistency, 54, 62, 75, 269
- magnetic charge, 184
- parity, 74, 139
- strangeness, 57
- constrained supermultiplet, \square supermultiplet, constrained constraint, 419
- continuity equation, 74, 249, 255, \square Noether, theorem
 - non-commutative, 229–230
 - QCD, 228, 551
- contraction, 510, 513
- contravariant vector, 497
- Cooper, 252
- coordinate system, \square system, coordinate correlation n -point functions, 419
- correlations at a distance, 434
- coset, 452
- cosmic rays, 39
- cosmological constant, 301, 341, 342
- cosmology, 341
- cotangent bundle, 497
- Coulomb, 38, 436
 - field, 20, 29, 136, 154, 195, 497
 - force, 20, 27, 48
 - gauge, 186, 203
 - potential, 128, 497
 - QCD, 235
 - units, 527
- counter
 - Cherenkov, 41
 - Geiger, 41
 - scintillation, 41
- coupling parameter, 21
 - electromagnetic, 21, 135, 187, 243, 288
 - variable, 210
 - strong, 235, 245
 - variable, 243, 245
- covariant derivative, 497
 - commutative, non-relativistic, 167, 168
 - commutative, relativistic, 191
 - general, 328
 - gravitational, \square —, spacetime
 - non-commutative, relativistic, 225, 226
 - spacetime, 322, 514
- covariant vector, 498
- covering, 90, 176, 351, 471, 482, 487, 498
- Cowan, 54
- Cox, 74
- CP -violation, \square violation, CP -symmetry
- Cronin, 61, 142
- current,
 - \square continuity equation, Noether, theorem and symmetry, 255, 271
 - electric, 183
- fermion
 - color, 228
 - electromagnetic, 192
 - electroweak, 268, 275, 278
 - gauge, \square gauge, current
 - Loos–Chern–Simons, 247
 - neutral, 269
 - flavor-changing, \square FCNC
 - probing, 416
- curvature, 498
 - differential form, 327
 - invariant
 - Kretschman, 334
 - quadratic, 334
 - scalar, 326
 - Ricci tensor, 326
 - Riemann tensor, 325
- d'Alembert equation, 186
- dark
 - energy, 301, 342
 - matter, 301
- Davis, 55
- Debye, 47
- decay, 38, 57, 70, 72, 77, 95, 97, 112, 113
 - $A \rightarrow B + C$, 116
 - J/ψ particle, 63
 - β , 34, 40, 53
 - γ , 40
 - half-life, 110
 - lifetime, 110
 - rate, 117
 - strangeness-violating, 65
 - two-particle, 113
- deformation, 434
- Democritus, xi, 37, 43, 71, 397, 523
 - atomism, 444
- Descartes, 5, 142, 177, 187
 - coordinate, 87, 318
 - lattice, 453
 - product, 495
- detailed balance, 53, 141
- DeWitt, 232
- de Sitter, 358
- differential cross-section, 45, 112, 202
- dimensional analysis, 15, 257, 362, 370, 380, 391, 527, 528
- Dirac, 13, 51, 54, 57, 133, 140, 187, 227, 313, 357, 405, 420
 - conjugation, 176, \square conjugation, Dirac
 - dual charge quantization, 187, 189, 444
 - equation, 173, 180
 - Hamiltonian, 181
 - Lagrangian density, 180
 - quantization, \square quantization, Dirac
 - spinor, 174, 177, 266
 - string, 187, \square magnetic monopole
- Dirichlet, 402
- discretuum, 405
- Distler, 402
- domain, 498
- dual resonant model, 398
- duality, 3, 399

- electromagnetic, 185, 294
- gravity/gauge, 404
- particle-wave, 48
- T-duality, 401
- Dyson, 122
- Eckart, 149
- Eddington, 335, 350
- effective cross-section, \mathbb{F} scattering
- Eichten, 154
- eigenstates of weak interactions,
 \mathbb{F} quark mixing
- eightfold way, 59, 77, 151
- Einstein, 47, 48, 54, 83, 92, 296, 352, 357, 406, 431
 - equations
 - analogue of Gauss–Ampère laws, 329
 - vacuum, 327
 - with matter, 328
 - Einstein–Hilbert action, 327
 - Einstein–Rosen bridge, 349, 352, 498
- electrodynamics
 - classical, 182, 185
 - quantum, 34, 124, 172, 191, 211
 - supersymmetric, 387
- electron, 11, 39, 43, 51
 - neutrino, 287
 - number, 56
- electron–positron
 - annihilation, 201
 - creation, 201
- elementary particle, xi, xii, 4, 30, 37, 46, 49, 56, 62, 67, 71, 251, 397, 402, 408, 411, 471, 523
 - experiment types, 38, 39
- emergent, xi, 446
 - complement to Democritean atomism, xiv
- energy
 - condition, 348
 - negative, 51
- energy-momentum 4-vector, \mathbb{F} 4-momentum
- energy-momentum tensor density, 329
- Englert, 252
- Eötövös experiment, 316
- Epicurus, 43
- equations of motion, 15, 180, 191, 192, 211, 220, 228–230, 247, 248, 251, 253, 256, 260, 263, 264, 327, 374, 416, 458
- equivalence, 499
- Eratosthenes, 4
- ergoregion, 338
- ergosurface, 338
- Euler, 398, 416
 - angles, 66, 485
 - characteristic, 375, 499
- Euler–Lagrange equations,
 \mathbb{F} equations of motion
- event horizon, 30
- exceptional divisor, 339
- excess energy density, 258, 265
- experiment
 - new conceptual set-up, 303
- extension
- electrodynamics, 294
- fermionic, 359
- Gödelian: quantum physics, 521
- generally relativistic, 24, 296
- M - and/or F -theoretic, of superstrings, 31, 403, 406, 441–444
- not falsification, 7
- of Ampère’s law, for self-consistency, 294
- of color symmetry, 306
- of gauge symmetry, 308
- of models, possibly perpetual, 7
- of the Standard Model, 303
- of weak symmetry, 305
- quantum, 10, 26, 298, 311, 357
- rationale for, 308
- relativistic, 8, 311
- spatial, of elementary particles, 30, 434
- specially relativistic, 295
- supersymmetric, 358, 361, 365
 - of Lie algebras, 367
 - of the Poincaré algebra, 370
- extremal black hole, 499
- F -theory, 404
- Faddeev, 232
- falsifiability, 9
- falsification, \mathbb{F} extension
- Fano, 430
- Faraday, 171, 182, 294
- FCNC, 67, 269
- Fermi, 13, 54, 56, 57, 64, 357
 - golden rule, 113
 - interaction, \mathbb{F} interaction, contact, Fermi
 - model of weak interaction, 64
- fermion, 499
 - left-handed, \mathbb{F} chirality, helicity
 - number of families, 301
 - right-handed, \mathbb{F} chirality, helicity
- fermionic integration, \mathbb{F} Berezin integration
- fermionic number, 369
- fermionization, 423
- Feynman, 19, 51, 54, 122, 142, 151, 205, 398, 411
 - diagram, 103, 110, 116, 121, 137, 143, 149, 191, 196, 198, 206, 212, 215, 217, 235, 239, 241–243, 268
- rules, 191
 - electroweak interaction, 279
 - QCD, 232
 - QED, 193
 - toy, 116
- fibration, 427, 499
- field
 - chromodynamics, 247, 324
 - electric, 48
 - electromagnetic, 32, 33, 72, 135, 171, 182, 185, 186, 190, 195, 226, 247, 256, 324, 373, 386
 - gauge, 182, 226, 325
 - gravitational, 326
 - weak, 72
- field (mathematics), 499
- field (physics), 499
- Fierz, 516
- fine structure, 21, 134
 - constant, \mathbb{F} coupling parameter

- Finkelstein, 350
Fischler, 31, 403
Fitch, 61, 142
FitzGerald–Lorentz contraction, 67, 86
flavor, 62, 76, 232, 499
 approximate conservation, 77, 153
 bottom, 63
 charm, 61, 63
 down, 49
 isospin, 49
 strangeness, 57
 top, 63
 up, 49
FLRW
 geometry, 341
flux, 27
Fok, 169
force
 localized, 27
 range, 27
form-factor, 216
formula (scattering)
 Mott, 202
 Rosenbluth, 217
 Rutherford, 202
Fourier, 52, 399
fractal, 399
Fradkin, 494
Frautschi, 399
Friedan, 401
Friedman, 341
Fritzsch, 61, 160
Fronsdal, 350
Fuller, 352

 g -factor, 133
Galilean symmetry, 295
Galileo, 8
Garwin, 74
Gates, 365
gauge
 boson, 67
 ate the Goldstone mode, 265
 mass, 251, 264
 charge, 229
 current, 229
 weak, 268
 field, 505, 506 field, gauge
 fields, 499
group
 abelian, 169
 gravity, 323
 non-abelian, 224
interaction, 300, 406
 $V-A$ type, 267
 relative intensity, 300, 303
 relative magnitude, 302
potential, 500, 505
 abelian, 168, 182, 186
 gravity, 323
 non-abelian, 225
principle, xiii, 39, 146, 295, 300
universal, 371
symmetry, 146, 223, 263, 296
 abelian, 169
 non-abelian, 63, 223
theory, 63
 gravity, 165, 324
 Yang–Mills, 50, 165, 223, 224, 508
transformation, 189, 225, 251
 abelian, 168, 186, 186, 189
 gravity, 323
 non-abelian, 224
gauged supermultiplet, 508 supermultiplet, gauged
Gauss, 7, 171, 182, 228, 294, 428, 436, 439
Gauss–Ampère law
 QCD, 229, 229–230
 QED, 183, 192
Geiger, 45
Gell-Mann, 57–61, 142, 151, 160
 matrices, 224, 476
geodesic, 331
geometric quantization, 508 quantization, geometric
geometrization of physics, 500
geometry
 anti de Sitter, 342
 brane, 431, 432, 433, 436
 compactification, 400, 422, 424, 427, 431–433, 438,
 443
 de Sitter, 342, 433
 engineering, 348
 Gödel, 344
 Kasner, 343
 Minkowski, 342
 Ricci-flat, 343
vacuum
 Kerr, 337
 Kerr–Newman, 338
 Kerr–Tomimatsu–Sato, 339
 Reissner–Nordstrøm, 337
 Schwarzschild, 333
with matter
 FLRW, 341
 Gödel, 344
 Lanczos–Stockum, 346
 wormholes, 508
Georgi, 67, 306
Georgi–Glashow, 508 GUT, Georgi–Glashow
Gervais, 364, 400
ghost field, 500
GIM mechanism, 154, 267, 269
Ginzburg, 252, 402
Glashow, 61, 63, 67, 300, 306
glueball, 239
gluon, 127, 225, 229, 230, 232, 501
GNN formula, 57, 60, 75, 146
 weak, 275, 276, 278
Gödel
 geometry, 344
 incompleteness theorem, 7, 406, 501, 519
 radius, 344
Gol'fand, 358, 365
Goldstone, 68, 252, 433

- mode, 68, 265
 theorem, 255, 255
 Gordon, 186
 Goto, 401, 410
 Gottfried, 154
 Gram, 18
 Gram–Schmidt procedure, 18, 501
 grand desert, 302, 303
 Grassmann, 174
 gravity, 24, 293, 296, 315, 327, 371, 372, 400, 404, 406–
 408, 431, 432, 444
 force, 331
 quantum, 334, 340, 388
 Green, 401, 405, 434
 Greenberg, 61, 160
 Greene, 425
 Gribov, 399
 Griffiths, 43
 Grisaru, 365
 grok, xii
 Gross, 64, 402, 423
 group, 451, 501
 abelian, 452
 commutative, 452
 Lie, 454
 non-abelian, 452
 non-commutative, 452
 Gubser, 404
 Guralnik, 252
 Guranlik–Hagen–Kibble effect,
 Higgs, effect
 GUT
 Georgi–Glashow, 306
 models, 308
 Pati–Salam, 304
 Haag, 310, 370
 Haag–Lopuszanski–Sohnius, 370
 hadron, 127, 501
 hadronization, 212
 Hagen, 252
 Hahn, 53
 Hamilton, 18, 181, 401, 410, 416
 action, 38, 91
 supersymmetric, 381
 Hamiltonian, 18
 canonical, 92
 density, 171, 257
 Dirac, 180
 eigenstate oscillation, 286
 field latency correction, 136
 flavor hierarchy, 153
 gauge potential terms, 170
 LHO, 359
 LHO+fermion, 359, 361
 LHO, supersymmetric, 361
 magnetic corrections, 132
 non-relativistic, 128
 principle, 92, 227
 relativistic correction, 130
 Zeeman effect, 153
 Han, 61, 160
 Harmer, 55
 harmonic oscillator
 linear, 359
 supersymmetric, 362
 Harvey, 402, 423
 Hausdorff space, 496
 Hawking, 340
 Heisenberg, xi, 26, 48, 49, 67, 145, 297, 398
 indeterminacy principle, 26, 33, 67, 72, 73, 103
 uncertainty, —, indeterminacy
 zone, 105
 Heitler, 13
 helicity, 177, 501
 Hermite conjugation, — conjugation, Hermite
 Hibbs, 19
 Higgs, 252
 boson, 67, 306
 critical energy, 266
 effect, 256, 265, 266
 effect in electroweak interaction, 276
 Higgs–Kibble effect, — Higgs, effect
 Hilbert, 18, 359, 406
 Hilbert space, 359
 bosonic, 359
 bosonic–fermionic, 360
 supersymmetric, 362, 366
 holography principle, 31, 403
 Homestake, 525
 homotopy, 407
 class, 501
 't Hooft, 31, 248, 276, 403
 Horowitz, 402, 424
 Hubble, 342
 Hume, 5
 hydrogen atom, 18, 27, 45, 72, 95, 127, 129, 134, 136, 153,
 174, 195, 472
 hyper-spherical coordinates, 341
 hypercharge, 62
 weak, 275, 289
 hypersurface, 502
 hypothesis
 chronology protection (Hawking), 347
 cosmic censorship (Penrose), 337
 history preservation (Novikov), 347
 Iizuka, 63, 77
 Iliopoulos, 61, 63
 image, 502
 in-line question, xiv, 17, 18, 40, 46, 72, 90, 92, 97, 100,
 102, 104, 109, 114, 131, 137, 140, 141, 147, 154,
 155, 253, 263, 359, 520
 indeterminacy principle, — Heisenberg, indeterminacy
 principle
 inertial system, 84
 injection, 502
 intact supermultiplet, — supermultiplet, intact
 integral contour, 425
 integrality, 45, 187, 189–190, 405, 442
 integration
 fermionic, — Berezin integration
 path, — quantization, Feynman–Hibbs
 interaction, 146

- chromodynamical, 234
contact, 497
Fermi, 58, 64
Yukawa, 50, 58, 72, **112**
electromagnetic, 29, 31, 67, 112
electroweak, 31, 33
fundamental, 37
inter-molecular, **112**
mediated, 49
mediator, 49, 52, 64
mass, 72
range, 72
residual strong, 29
strong, 28, 29, 31, 33, 34, 57
weak, 26, 29, 31, 33, 34, 57, 67
Yang–Mills, 50
Yukawa, 243, \square interaction, contact, Yukawa
invariant norm, 509
isometry, 502
isomorphism, 502
isospin, 49, **145**, 146, 148, 150, 153, 160, 234, 411, 473
addition, 155
weak, 138, **275**, 275, 288, 289, 306, 367
- Jacobi, 181, 320
identity, 227
Jordan, 48, 423
- Kachru, 402
Kähler, 424, 443
Kałuża, 400, 424, 496
KamiokaNDE, 502
kaon, 69, 77, 142, 144, 145, 157, 317
Kasner geometry, 343
Kastler, 310
Kepler, 129, 432, 436
kernel, 502
Kerr geometry, 337
Kerr–Newman geometry, 338
Kerr–Tomimatsu–Sato geometry, 339
Kibble, 252
kinematics, 95
Klebanov, 404
Klein, 186, 223, 400, 424, 496
Klein–Gordon equation, 172, 186
Kobayashi, 61, 63, 65
Konopinski, 55
Korzybsky, 446
Kramers, 48, 398
Kronecker symbol, 502, 509
Kronig, 398
Kruskal, 350
Kruskal–Szekeres
coordinates, **350**
diagram, 350
Kuhn, 10
Kurrelmeyer, 74
- Lagrange, 92, 416, 420
Lagrangian, 92
density, 94, 171, 183, 191, 192, 230, 249, 251, 256, 260
Dirac, 180
- QCD, 228, 247
QED, 191
supersymmetric, 381, 383
Lamb shift, 135
Lanczos–Stockum geometry, 346
Landau, 142, 245, 252, 402
Landau–Ginzburg
model, **252**
orbifold, 402
landscape, 404
Laplace, 129
Laplace–Runge–Lenz vector, 129
Larmor, 17
lattice QCD, 64
law of Nature, 70
Lederman, 74
Lee, 74, 139, 276
Leeuwenhoek, 4
Leibniz, 8
Lemaître, 335, 341, 350
Lenz, 129
lepton, 52, 54, 56, 63, 67, 503
conserved numbers, **75**
Leucippus, 43, 523
Levi-Civita
symbol, 503, 509
Lewis, 48
LHC, 68
Lie
algebra, 175, 368, **454**
bracket, **454**
group, **454**
Likhtman, 358, 365
line element, **319**, 509
linear algebra, **513**
local symmetry,
 \square gauge, symmetry
London, 13, 169
loop quantum gravity, \square LQG
Loos, 247
Łopuszanski, 370
Lorentz, 123, 133, 140, 175, 312, 440
boost, 85, 142, 176
contraction, \square FitzGerald–Lorentz contraction
force, 48
gauge, 203
general transformation, 88, 294, 295
group, 90, 176, 377
invariant, 89, 186
Lorenz gauge, 186, 294
LQG (loop quantum gravity), 406, 413
luxon, **41**, 503
- M*-theory, 403
magma, 503
magnetic charge, \square magnetic monopole
magnetic moment anomaly, 551
magnetic monopole, 182, 184, **187**
Wu–Yang construction, **188**
Mahmoud, 55
Maiani, 61, 63
Maldacena, 403

- Mandelbrot, 399
 Mandelstam, 218, 398
 variables, 99
 Mandula, 369
 manifold, 503
 Marsden, 45
 Marshak, 51
 Martinec, 402, 423
 Maskawa, 61, 63, 65
 mass
 elementary fermions, 283, 300
 fermion, 267
 gauge boson, 251, 264, 278
 gravitational, 316
 imaginary, 257
 in the broken symmetry phase, 258
 inertial, 316
 neutrino, 287, 288
 shell, 104, 180, 204, 207, 220, 503
 W^\pm -boson, 278
 Z^0 -boson, 278
 massless particle, 94
 Maxwell, 74, 171, 231, 294, 312
 equations, 182, 184, 294, 295
 McIlwraith, 74
 measurable physical quantity, 208,
 \Leftrightarrow renormalization
 Meitner, 53
 Mendeleev, 58, 59
 meson, 49, 56, 58, 70, 127, 153, 503
 metamathematics, 420
 metric tensor, 89, 296, 319
 Mills, 50, 63, 223, 406, 436
 minimal coupling, 503
 Minkowski, 343, 444
 Miyazawa, 364
 model, 309, 416
 Bohr's (of the atom), 45
 planetary (of the atom), 45,
 \Leftrightarrow Rutherford, planetary modes
 quantum-consistent, 406
 Møller, 198
 monoid, 503
 Monte Carlo simulations, 64
 Mott, 196, 202
 formula, 202, 221
 moving frame, 516
 multipole expansion, 503
 muon, 51, 56, 140
 decay, 54, 284
 lifetime, 86
 neutrino, 287
 number, 56
 Nakano, 57
 Nambu, 61, 160, 252, 399, 401, 410
 Nambu–Goldstone mode, \Leftrightarrow Goldstone, mode
 Nambu–Goto action, 401, 410
 Ne'eman, 59
 Neddermeyer, 51
 von Neumann, 415
 neutrino, 53, 54
 mass, 288
 mixing, 286, 301
 oscillation, \Leftrightarrow —, mixing
 problem, 286, 287, 525
 neutron, 46
 Newman, 338
 Newton, 7, 8, 47, 84, 293, 300, 432, 436
 G_N , 24, 35, 297, 526
 mechanics, 295
 Nielsen, 399
 Nishijima, 57
 Noether, 146
 theorem, 39, 55, 69, 73, 138, 166, 229, 271, 461, 504
 nonphysical components, 504
 Nordstrøm, 171, 337, 400, 403, 424, 496
 normal subgroup, 504
 nuclear reactor, 39
 nuclear source, 39
 nucleon, 46
 O'Raifeartaigh, 369
 Ockham's principle, 3, 33, 308, 505
 off-shell, 104, 389, 393
 Okubo, 58, 63, 77
 Okun, 169
 on-shell, 104, 204, 389
 open questions, 64, 69, 76, 77, 127, 140, 144, 155, 183,
 230, 237, 246–249, 271, 284, 288, 290, 300, 301,
 303, 305, 323, 334, 337, 347, 365, 388, 389, 393,
 395, 402, 404, 426, 428, 434, 436, 437, 439, 444,
 475, 522
 orthogonalization procedure, \Leftrightarrow Gram–Schmidt procedure
 OZI rule, 63, 77
 P -symmetry, \Leftrightarrow parity
 P -violation, \Leftrightarrow violation, parity
 Pais, 57, 142
 Pandora's box, 57
 paradox
 ladder, ruler, twin, \Leftrightarrow —, relativistic
 relativistic, 34, 346
 parity, 138, 304,
 \Leftrightarrow violation, parity
 partition functional, 419, 426
 Pati, 304
 Pati–Salam, \Leftrightarrow GUT, Pati–Salam
 Pauli, 13, 54, 140, 150, 173, 179, 357, 360, 405
 exclusion principle, 38, 60, 61, 159, 360, 505
 Gruppenpest, 150
 Penrose, 337
 process, 338
 perturbation Hamiltonian, 18
 Petersson, 422, 443
 phantom energy, 342
 phase transition, 253, 258, 274, 299, 306
 philosophy
 eastern, 151
 essays, 405
 of Nature, 293
 of science, 70
 positivism, 44
 photoelectric effect, 47

- photographic emulsion, 42
photon, 39, 47, 48, 193, 505
physical components, 505
pion, 50, 51, 69, 139, 143, 147, 155
 decay, 54, 140, 284
 virtual, 243
 Yukawa's strong interaction model, 58
Planck, 47
planetary model, \square Rutherford, —
Plessner, 425
PMNS-matrix, \square neutrino, mixing
Poincaré algebra, 358
point-like, 505
Polchinski, 403
Politzer, 64, 154
Polyakov, 248, 401, 404
 action, 401
Pomerančuk, 399
pomeron, 399
Popov, 232
Popper, 9, 310, 406, 520
positron, 13, 39, 52
positronium, 136, 203
 lifetime, 205
potential, 505
Powell, 51, 54, 57
pragma, 11, 124
preon, 68
product
 direct, \square Descartes, product
 tensor, 507, 514
proton, 44
 decay, 306, 307

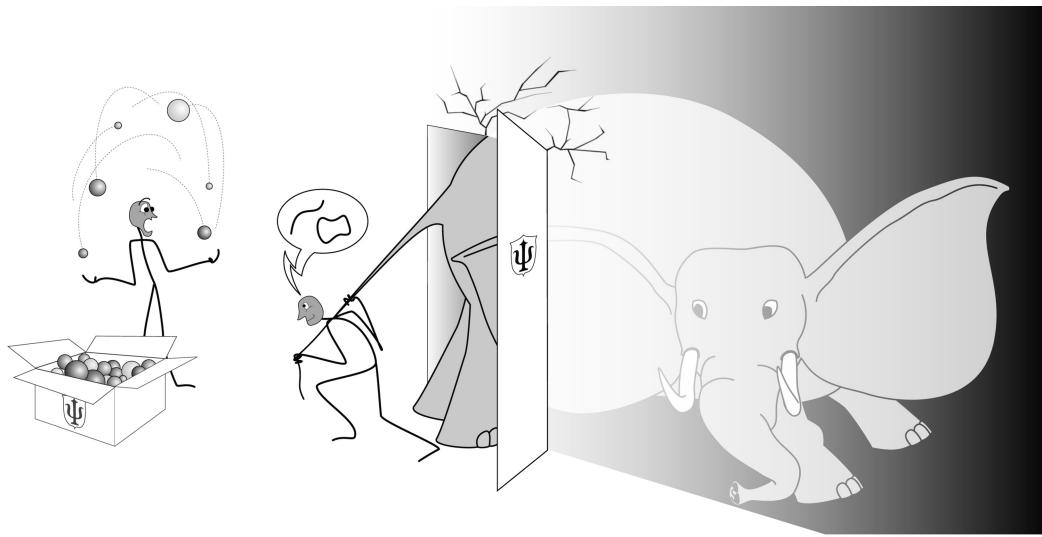
quantization, 12
 angular momentum, 22, 465
 BFV, 418, 420, 494
 Bohr, 45
 BRST, 418, 494
 BV, 418, 420, 495
 canonical, 181, 407, 418
 correspondence, 172
 Dirac, 189, 363, 420, 498
 electromagnetic field, 135
 Feynman–Hibbs, 418
 geometric, 500
quantum, 505
quark, 28, 59, 67, 127, 153, 232
 bound state, 70
 confinement, 28, 155, 246
 flavor, 62
 mixing, 300
 Cabibbo, 65
 Kobayashi–Maskawa, 61, 65
 model, 60
 experimental confirmation, 157, 159, 161, 162, 218,
 219, 221
 quark–antiquark production, 212
 quarkonium, 153
 bottomonium, 154
 charmonium, 154
 toponium, 154
quintessence, 342
quotient space, 453

radiation
 alpha (α), 40
 beta (β), 40
 black hole, \square —, Hawking
 electromagnetic, 25, 40
 gamma (γ), 40
 Hawking, 340
 Röntgen, 40
 synchrotron, 39
 X-rays, 40
Randall, 431
range (of a mapping), 505
rank (of a mapping), 505
rank (of a tensor), 511
real
 annihilation, 137
 particle, 113
 physical phenomenon, 13
 process, 104, 230
 state, 73
 values, 209
 W^\pm - and Z^0 -particle, 33
 world, 12
recycling, 400, 402–405, 423–426, 432
reference system, \square system, coordinate
Reines, 54
Reissner, 337, 403
Reissner–Nordström geometry, 337
relativity
 extent, 86
 length, 86
 simultaneity, 85
 time duration, 86
 velocity, 86
renormalization, 120, 206, 208, 373
 conceptual origin, 123, 313
 flow, 210
 group, 210
resonance, 399
rest energy, 92
Ricci, 343
Richter, 63
Riemann, 343
 tensor, 296
ring, 505
Robertson, 341
Roček, 365
Rochester, 57
Rohm, 402, 423
roots, 398
Rosen, 352
Rosenbluth formula, 217, 218, 221
Rouet, 232, 494
Rubbia, 66
Runge, 129
Rutherford, 45, 196
 formula, 45
 planetary model, 11, 45, 310

- scattering, 27, 28, 45
- Saharov, 144
- Sakata, 151
- Sakita, 364, 400
- Salam, 50, 63, 67, 223, 300, 304, 365
- Sato, 339
- scalar, 511
 - density, 94, 320, 511
- scattering, 38, 47, 98, 113, 119
 - Bhabha, 199
 - Compton, 200
 - deep inelastic, 60
 - effective cross-section, 111, 120, 137
 - elastic, 95, 118
 - explosive, 95
 - fissile, 95
 - fusing, 95
 - Mott, 196
 - Møller, 198
 - process threshold, 100
 - Rutherford, 27, 60, 128, 196
 - sticking, 95, 99
- Scherk, 400
- Schmidt, 18
- Schrödinger, 13, 51, 169
- Schrödinger equation, 128, 165, 172
- Schroer, 405
- Schwarz, 400, 401, 405
- Schwarzschild geometry, 333
- Schwinger, 67, 122
- scientificity, 9
- semidirect product, 505
- semidirect sum, 506
- semigroup, 506
- Shaw, 50, 63, 223
- Shenker, 31, 403
- Shiffer, 252
- Siegel, 365
- signature, 506
- Simons, 247
- singularity
 - compactification, 427
 - Dirac monopole, 188
 - fibration, 427
 - naked, 337, 339, 499
 - spacetime, 334, 434, 499
- Slater, 48
- small resolution, 434
- Smolin, 405
- Sohnius, 370
- solar neutrino problem, $\bar{\nu}$ neutrino, problem
- soldering form, 516
- Sommerfeld, 21
- source probing, 416
- space
 - configuration, 419
 - domain, 31, 416
 - target, 31, 409, 412, 416
- spacetime, 87, 90, 91, 300, $\bar{\nu}$ geometry
 - asymptotically flat, 333
- spacetime 4-vector, 87
- spacetime foam, 407
- span, 506
- spin, 133, 506
- spin-orbital interaction, 21
- spin-statistics theorem, 38, 234, 494, 499
- stabilization
 - atom, 371
 - mass hierarchy, 372
 - vacuum, 371
- Standard Model, xii, 38, 67, 67, 251, 288, 298, 402, 406
- statistics
 - Bose-Einstein, 357, 494
 - Fermi-Dirac, 357, 499
- Stevenson, 51
- Stokes, 189
- Stora, 232, 494
- strange particles, 56
- Strathdee, 365
- Street, 51
- string, 28, 399
 - critical dimension, 413
 - Dirac, 187
 - model
 - basic five, 403
 - heterotic, 402
 - IIA, 401
 - IIB, 401
 - open, 401
 - superstring, 10, 71
 - theory, 397, 422
 - stringy duality, 426
- Strominger, 402, 424, 439
- structure
 - absent, 26, 68, 505
 - algebraic, 383, 427, 512, 513
 - algebra, 174, 358, 368, 454
 - diagonal group, 249
 - group, 39, 70, 138, 210, 223, 323, 364, 451
 - superalgebra, 370
 - complex, 497
 - elementary particle physics, 408
 - fine, 21, 134, 136, 235, 302
 - hyperfine, 22, 134, 136, 157
 - nuclear, 365
 - physical
 - model, xii, 38, 78, 140, 170, 193, 282, 300, 308, 309, 426
 - object, 25–28, 30, 37, 60, 133, 216, 230, 313, 335, 348, 402, 407, 445, 446
 - theory, xii, 3, 31, 308, 310, 420
 - string theory, 422
 - stringy duality, 426
- structure function, $\bar{\nu}$ form-factor
- Struminsky, 61
- Stückelberg, 50, 51, 56, 142
- Stückelberg-Feynman interpretation, 175, 506, $\bar{\nu}$ antiparticle
- Sturm-Liouville theorem, 19
- Sundrum, 431
- super-covariant derivative, $\bar{\nu}$ super-derivative
- super-derivative, 378, 491

- super-selection, 369
- superalgebra, 364
- superfield, 365, 379
 - anti-chiral, 382
 - chiral, 382
 - component field, 379
- supergravity, 365
- supermultiplet
 - constrained, 382, 389
 - gauged, 386, 389
 - intact, 389, 390
- superpotential, 384
 - non-renormalization, 372
- superspace, 365, 377
- superstring theory, \mathbb{F} string, theory
- supersymmetric state, 375
- supersymmetry
 - applications, 364
 - breaking
 - explicit, 376
 - obstruction, 363
 - spontaneous, 376
 - harmonic oscillator, 361
 - transformation, 377
 - surjection, 507
 - Susskind, 31, 399, 403
 - swamp, 404, 443
 - symmetrization, 513
 - symmetry, 39, 69, 146
 - approximate, 62, 73, 77
 - breaking vs. violation, 507
 - crossing, 52
 - global, 166
 - local, 166, \mathbb{F} gauge, symmetry
 - $SU(3)_f$, 59
 - Synge, 350
 - system
 - CM, 496
 - coordinate, 31, 52, 83, 85, 87, 90, 91, 101, 102, 115, 132, 140, 178, 183, 187, 190, 204, 253, 295, 299, 464
 - Cartesian, 87
 - co-rotating, 84
 - inertial, 83–85, 102
 - reference, \mathbb{F} —, coordinate
 - scientific, 309, 309
 - theoretical, 309
 - Szekeres, 350
 - T -symmetry, \mathbb{F} time reversal
 - T -violation, \mathbb{F} violation, I -symmetry
 - tachyon, 41, 104, 261, 400, 503, 507
 - tangent bundle, 507
 - tardion, 41, 261, 507
 - tau-lepton, 52, 286
 - neutrino, 287
 - number, 56
 - Tavchelidze, 61
 - tensor, 511
 - algebra, 512
 - calculus, 509
 - density, 511, 511
 - weight, 511
 - rank, 511
 - type, 511
 - tetrad, 516
 - textbooks, xii, 147, 189, 193, 232, 274, 315, 358, 376, 437, 451, 453, 462, 489
 - theorem
 - addition of angular momenta, 473
 - Bertrand, 408
 - Birkhoff, 333
 - classical (axial-)vector symmetry, 271
 - Coleman–Mandula, 370
 - completeness of Dirac matrices, 487
 - CPT , 142
 - Gödel, 501, 519
 - Goldstone, 252, 255, 255
 - Haag–Łopuszanski–Sohnius, 370
 - Noether, 461
 - non-renormalization of superpotential, 372
 - O’Raifeartaigh, 369
 - quotient group, 483
 - supersymmetric action, 381
 - Weinberg–Witten, 249
 - Wigner–Eckart, 150, 475
 - Witten (supersymmetry breaking), 363
 - theoretical system, 295, 298, 309
 - theory, 309
 - of relativity, general, 24, 31, 83, 169, 293, 298, 315, 371
 - of relativity, special, 31, 48, 83, 83, 298, 310, 371
 - quantum, 26, 31, 48, 127, 185, 298, 310
 - scientific, 9
 - string, 397
 - Theory of Everything, xiv, 12, 409, 446
 - Thomson, 43, 313
 - effect, 47
 - thought experiment, 9, 27
 - thought-construction, 187
 - time dilation, 86
 - time reversal, 138
 - time-travel, 346, \mathbb{F} closed time-like curve
 - Ting, 62
 - Tomimatsu, 339
 - Tomonaga, 122
 - topological space, 507
 - toponium, 154
 - torsion, 498
 - tourist guides, xii
 - transformation
 - anti-linear, 140
 - gauge, \mathbb{F} gauge transformation
 - general coordinate, 319
 - phase, 168, 170, 189
 - type (of a tensor), 511
 - Tyutin, 232, 494
 - $U(1)$ anomaly, 61
 - ultraviolet catastrophe, 47
 - unification, 31, 251, 293, 300, 303, 304, 357
 - unit systems, 15
 - universe, \mathbb{F} geometry
 - unmeasurable

- coordinates, 83, **321**
- phase, 166, 170, \mathbb{Z}_2 gauge transformation
- unobservable, \mathbb{Z}_2 unmeasurable
- $V-A$ interaction, 267
- Vafa, 402
- van der Meer, 66
- vector, **511**
 - causal, 348
 - contravariant, 88
 - covariant, 88
 - light-like, 90, 348
 - null, **90**, 348
 - space-like, **90**, 352
 - spatial, \mathbb{R}^3 —, space-like
 - temporal, \mathbb{R} —, time-like
 - time-like, **90**, 348
- vector bundle, **507**
- vector space, **508**
- Veltman, 276
- Veneziano, 398
 - amplitude, **398**
- Vilkovisky, 494, 495
- violation
 - C -symmetry, 141
 - CP -symmetry, 61, 66, 142, 249, 301
 - strong, 247
 - parity, 74, 139, 140, 305
 - is maximal, 140, 179
 - strangeness, 65
 - T -symmetry, 141
- virtual
 - annihilation, 141, 241
 - particle, 33, 49, 67, 194, 245
 - photon, 135, 207, 212
 - process, **104**, 106
 - state, 38, 73, 112
- Volkov, 365
- volume element, 510
- Walker, 341
- Ward–Takahashi identity, 69,
 - \mathbb{Z}_2 gauge, symmetry
- warp and weft, **xiii**
 - of fundamental physics, 293
- warp, weft and woof
 - of fundamental physics, 508
- weak hypercharge, \mathbb{Z}_2 hypercharge, weak
- weak isospin, \mathbb{Z}_2 isospin, weak
- weight (of a tensor density), **511**
- Weil, 422, 443
- Weinberg, 67, 252, 300
- Weinrich, 74
- Weisskopf, 173
- Wess, 365
- Weyl, 51, 140, 169, 179
 - spinor, 177, 177, 266
- Weyl’s construction, **478**, **511**
- Wheeler, 350
- Wick rotation, 90, 429
- Wightman, 310
- Wigner, 49, 145, 149
- Wigner–Eckart theorem, 147, 150, 234
- Wilczek, 64
- Witten, 363, 401, 402, 404, 405, 424
 - index, **363**, 363, 369, 375
 - supersymmetry breaking, **363**
- Woit, 405
- world, \mathbb{R}^4 geometry
- wormhole, 349, **352**
- Wu, 74, 139, 188
- Yang, 50, 63, 74, 139, 188, 223, 406, 436
- Yang–Mills interaction, symmetry, theory, **508**
- Yang–Mills theory, \mathbb{Z}_2 gauge, theory
- Yau, 402, 424–430, 438, 439, 443, 496
- Young, 479
- Yukawa, 50, 54, 56
 - field, potential, **508**
 - interaction, **508**, \mathbb{Z}_2 interaction, contact, Yukawa
- Zamolodchikov, 422, 443
- Zaslow, 439
- Zeeman effect, 153
- Zinn–Justin, 276, 495
- ZJBV-quantization, \mathbb{Z}_2 quantization, BV
- Zumino, 365
- Zweig, 60, 63, 77



To be continued...

