

Index

- 40 Eridani B, 113, 114
 47 Tucanae, 121
- accretion-induced collapse, 7, 101
 adiabatic index, 93
 age of our galaxy, 110
 age of the universe, 111
 anomalous X-ray pulsars, 122
 atomic mass evaluation, 152
 axion, 90
- β -equilibrium, 150
 β -function, 229
 Baade, Walter, 4, 147
 bag model, *see* MIT bag model
 Baluni, Varouzhan, 229
 baryon chemical potential, 45, 196
 baryon number, 44
 baryons, 209
 Baym, Gordon, 150
 Bell-Burnell, Jocelyn, 117
 bending of light, 12
 Bertsch factor, 182
 Bethe–Weizsäcker mass formula, 156, 173
 Bianchi identity, 28
 binary neutron stars, 275
 binary pulsars, 121
 binding energy
 per baryon, 49
 of nuclei, 152
 Birkhoff theorem, 30
 black dwarfs, 110
 black hole merger, 264
 black holes, 1
 Bodmer, Arnold, 226
 Bodmer–Witten hypothesis, 227
 body-centered cubic lattice, 151
 Bohr, Niels, 147
 Bonazzola, Silvano, 90
- Borromean system, 179
 Bose condensate, 86, 195
 Bose–Einstein distribution, 217
 bottom quark, 210
 BPS model, 150
 brown dwarfs, 6
 Buchdahl, Hans A., 35
 Buchdahl limit, 35, 234, 242, 261
 bulk limit, 201
 bulk matter, 40, 41, 172
- Cameron, Alastair G. W., 149
 canonical ensemble, 39
 carbon-oxygen white dwarf, 6, 110
 Cassini mission, 142
 causal equation of state, 82, 234, 261
 causality, 13, 242
 central compact objects, 122
 central energy density
 for the maximum mass configuration, 80
 central pressure, 118
 Cepheids, 119
 Chandra satellite, 136
 Chandrasekhar, Subrahmanyan, 93
 Chandrasekhar mass, 70, 95, 190
 Chandrasekhar maximum mass, 113
 charge chemical potential, 44, 46, 196
 charge neutrality, 44, 222
 global, 249
 local, 249
 charge number, 44
 charged droplets, 250
 charm quark, 210, 218, 236
 charmed baryons, 195
 chart of nuclei, 48
 chemical equilibrium, 45, 58
 chemical potential, 38, 42, 44, 58
 antiparticle, 43
 photon, 43

- chiral effective field theory, 85, 183, 184
 chiral symmetry, 183, 212, 244
 Christoffel symbols, 17, 20, 269
 cold dark matter, 90
 color charge, 210
 color superconductivity, 244
 column density, 136, 137
 Coma cluster, 275
 compactness, 74, 242, 288–290, 292
 maximum, 74, 76
 composition
 of β -equilibrated matter, 48
 with hyperons, 199
 Compton wavelength, 86
 confinement, 210, 244
 conservation of mass, 60, 63
 conserved quantum number, 44
 constant-sound-speed parameterization, 261, 262
 continuity equation, 27
 contraction of a tensor, 18
 core-collapse supernova, 6, 245
 cosmic rays, 135
 cosmological constant, 75
 Coulomb energy, 102, 250
 Coulomb interaction parameter, 109
 Coulomb lattice, 103
 Coulomb self energy, 101
 Coulomb term, 157
 covariant derivative, 16
 Crab pulsar, 124, 127, 129, 130, 136, 278
 critical condition for degeneracy, 108
 critical end point, 245
 critical mass density for neutrons, 47
 curvature scalar, 28
- dark matter, 64
 degeneracy factor, 46, 67
 degenerate iron core, 6
 Derrick's theorem, 90
 determinant of the metric, 32
 deuteron, 181
 dimensional reasoning, 71
 dipole moment, 125
 dipole radiation, 275
 Doppler shift, 11, 140
 double pulsar, 121, 138
 down quark, 210
 Duflo–Zuker model, 157
- early universe, 245
 eccentricity, 139, 282
 effective mass, 176–178
 effective range parameter, 182
 Einstein, Albert, 264
 Einstein equations, 29
 Einstein equivalence principle, 9
 Einstein–Maxwell equations, 89
 Einstein tensor, 28
- Einstein time delay, 141
 Einstein's quadrupole formula, 128
 Einstein's summation convention, 14
 electrodynamics, 43
 electroweak symmetry breaking, 44
 ellipticity, 128
 end points of stellar evolution, 5
 energy density, 25
 energy–momentum conservation, 27
 energy–momentum tensor for an ideal fluid, 62
 entropy, 38
 EOS, *see* equation of state
 equation of state, 33, 42, 237, 239
 of Akmal, Pandharipande, Ravenhall (APR), 183
 constant-sound-speed, 258
 free Fermi gas, 55
 for interacting fermions, 81
 interaction dominated, 95, 288
 nonrelativistic limit, 52
 relativistic limit, 52
 stiffest possible, 57
 ultra-relativistic limit, 54
 Euler equation, 27, 39, 40
 event horizon, 3
 exoplanets, 121
- face-centered cubic lattice, 152
 Facility for Antiproton and Ion Research (FAIR),
 160, 203, 245
 Facility for Rare Isotope Beams (FRIB), 160
 failed supernova, 6
 fast radio bursts, 122
 Fermi–Dirac distribution, 217
 Fermi energy, 46
 Fermi gas, 46
 Fermi momenta, 46
 Fermi's constant, 85
 finite range droplet model, 157, 180
 first-order phase transition, 246
 first stars, 6
 flavor mixing, 44
 four-vector, 14
 four-velocity, 22
 free energy, 39, 58
 Freedman, Barry A., 229
- Galilei, Galileo, 8
 gamma-ray burst, 265
 gauge symmetry, 266
 Geminga pulsar, 121
 GEO600, 264, 269
 geodesic equation, 269
 geons, 89
 Gerlach, Ulrich H., 253
 giant dipole resonance, 175
 giant monopole resonance, 175
 Gibbs energy, 155
 Glendenning, Norman K., 248

308

globular cluster, 110, 120
 glueballs, 209
 gluon condensate, 75, 244
 gluons, 210
 Goeppert-Mayer, Maria, 153
 Gold, Thomas, 120
 Goldreich, Peter, 132
 Goldstone boson, 213
 Goldstone theorem, 213
 grandcanonical ensemble, 39, 41
 grandcanonical potential, 44
 gravitational bending of light, 10
 gravitational binding energy, 32
 gravitational lensing, 113
 gravitational mass, 8, 32, 64
 gravitational redshift, 10, 15, 113, 140
 gravitational wave amplitude, 274, 278
 gravitational wave detector, 264, 269
 gravitational wave emission, 143
 graviton, 267, 268
 GW150914, 264
 GW170817, 265, 275, 284, 292

 H atmosphere, 115
 hadron gas, 218
 hadron phase, 244, 248
 hadrons, 209
 hard equation of state, 178
 Harrison, B. Kent, 148
 heavy-ion collisions, 245
 Heisenberg uncertainty principle, 86
 helicity, 269
 helium white dwarf, 110
 Hertzsprung–Russell diagram, 5
 Hewish, Anthony, 117
 hexagonal close packed lattice, 152
 Higgs boson, 90
 HII-regions, 136
 Hubble Space Telescope, 136
 Hugenholtz–van Hove theorem, 176, 230
 Hulse–Taylor pulsar, 121, 131, 138, 264
 hydrodynamics, 27
 hydrogen-helium white dwarf, 6
 hydrostatic equilibrium, 33, 61, 248
 hypernova, 6
 hyperon star, 205
 hyperons, 149, 195, 210

 ideal fluid, 26
 ideal gas pressure, 108
 inclination angle, 139
 incompressible fluid, 95, 288, 290
 inertial mass, 8
 inner crust, 239
 instanton, 44
 interaction mass scale, 82
 interaction terms, 186
 internal energy, 38

Index

interstellar medium, 136
 inverse β -decay, 4
 isolated neutron stars, 122
 ISOLTRAP collaboration, 160
 Itoh, Naoki, 235

 Jensen, Hans Daniel, 153
 Julian, William H., 132

 Kämpfer, Burkhard, 253
 KAGRA, 264, 269
 kaons, 90, 194
 Kaup, David J., 90
 Kepler's law, 279, 282
 Kerr, Roy, 3
 Kerr black hole, 3
 kilo-nova, 265

 Λ -hyperon, 195, 199
 Λ -potential, 202
 Landau, Lev, 4, 34, 63, 147
 Landau mass, 68, 74, 88
 Landau radius, 68, 74, 88
 Lane–Emden equation, 64
 Laplace equation, 16
 Large Hadron Collider (LHC), 135, 203, 245
 Larmor's formula, 125
 Laser Interferometer Gravitational-Wave
 Observatory (LIGO), 129, 264, 269, 273, 274,
 278, 292
 lattice gauge calculations, 210
 lattice gauge theory, 214
 lattice of nuclei, 166
 lattice QCD, 219, 244
 Lattimer–Prakash relation, 80
 Legendre transformation, 39, 58
 lepton, 194
 lepton chemical potential, 45
 lepton number, 44
 lifetime of stars, 111
 light-like, 13
 lighthouse model, 120
 LIGO, *see* Laser Interferometer Gravitational-Wave
 Observatory
 limiting causal equation of state, 77
 LISA (Large Interferometer Space Antenna), 274
 little green men, 117
 Lorenz gauge, 267
 Love, Augustus Edward Hough, 285
 Love number, 285, 288–291

 magic numbers, 48, 153, 160
 magnetars, 122, 130
 magnetic dipole moment, 125
 Mars, 142
 mass defect, 10
 mass–luminosity relation of stars, 111
 mass moments, 272

- mass–radius relation, 66
 hybrid star, 258, 261
 neutron star, 253
 for polytropes, 99
 stability analysis, 252
 white dwarf, 113, 252
 maximum angular frequency, 119
 maximum central energy density, 263
 maximum compactness
 of boson stars, 89
 of a free fermion star, 84
 selfbound stars, 79
 maximum mass
 boson stars, 87, 88
 from causality, 77
 for free neutron matter, 65
 MIT bag model, 76
 maximum redshift, 79
 Maxwell construction, 155
 McLerran, Larry D., 229
 mean mass density, 1
 Mercury, 142
 mesons, 194, 195, 209
 metric compatible, 17
 microcanonical ensemble, 38
 MIT bag constant, 75
 MIT bag model, 75, 78, 212, 213, 224, 228
 mixed phase, 247, 248
 model atmospheres, 113
 moment of inertia, 123, 276, 277
 moment of inertia prefactor, 123
 muon, 194, 196, 199

 Negele, John W., 168
 neon-oxygen-magnesium core, 6
 neutralino star, 90
 neutrino star, 90
 neutrinos, 44, 194
 neutron-drip density, 48, 160, 164
 neutron lifetime, 196
 neutron matter, 64, 238, 239
 neutron pairing energy, 167
 neutron-rich nuclei, 104, 158, 160
 neutron star, 253
 cooling, 167
 maximum energy density, 208
 maximum mass, 148, 149, 192
 maximum radius, 208
 minimum mass, 190
 radius, 292
 thickness of the atmosphere, 106
 thickness of crust, 169
 neutron star merger, 208, 245, 265, 293
 neutron superfluid, 166
 neutronization density, 104
 Newton, Isaac, 8
 Newton's law, 8
 nonrelativistic limit, 47, 50, 54

 nonvanishing vacuum expectation value, 75
 nuclear equation of state, 178
 nuclear liquid-gas phase transition, 245
 nuclear mass, 152
 nuclear matter, 173
 binding energy, 173
 incompressibility, 175, 178
 saturation density, 77, 174
 Fermi momentum, 174
 nuclear shell model, 153
 Nucleon Based Ion Collider Facility (NICA), 245
 nucleon–nucleon two-body interaction, 181
 null vector, 23
 number density, 46

 Ω^- -hyperon, 195
 one-form, 14
 onset
 of hyperons, 198
 of neutrons, 196
 Oppenheimer, J. Robert, 34, 63, 148
 oscillation period, 119
 of neutron stars, 119
 of white dwarfs, 119
 oscillations of compact stars, 118
 outer crust, 187, 239
 thickness, 162

 Pacini, Franco, 119
 pairing energy, 157
 parametrized mass models, 156
 particle composition, 44
 particle number, 38
 pasta phase
 gyroid phase, 172
 lasagna phase, 171
 parking-garage structure, 172
 spaghetti phase, 171
 stability, 171
 structures, 188
 waffle phase, 172
 Pauli-forbidden, 196
 pentaquarks, 209
 perfect fluid, 30
 periastron advance, 142
 perturbative QCD, 85, 215, 219, 229–231, 238, 239
 Pethick, Christopher, 150
 phase coexistence line, 249
 phase equilibrium, 247
 phase shift, 182
 phase transition, 237, 257, 261, 293
 pion, 90, 194, 199, 213, 218
 pion decay constant, 85
 Planck mass, 85
 planetary nebula, 6, 110
 planets, 6
 plasma frequency, 136
 plasma parameter, 109

310

plunge phase, 283
 Polaris, 119
 polytrope, *see* polytropic equation of state
 polytropic equation of state, 54, 240, 241, 288, 289
 polytropic power, 55, 187
 post-Keplerian parameters, 140, 145
 pressure, 25
 pressure integral, 50, 216
 primordial black holes, 6
 Procyon B, 113, 115
 projection operator, 273
 proper time, 15, 23
 proper volume element, 32
 pseudo-critical temperature, 219
 pseudo-Goldstone boson, 213
 pulsar
 in binary systems, 131
 characteristic age, 130
 characteristic magnetic field, 126, 129
 electric force, 133
 energy loss, 124
 fastest known pulsar, 120
 glitches, 167
 light-cylinder, 134
 mass constraint, 243
 polar cap, 134
 recycled, 131
 spin-down limit, 129, 278
 spin precession, 144
 pure neutron gas, 52

QCD
 β -function, 215
 critical temperature, 214, 219
 fine-structure constant, 214
 phase transition, 214, 244
 renormalization scale, 215
 strong coupling constant, 214
 running, 215
 vacuum, 75
 quadrupole moment, 272
 quantum chromodynamics, *see* QCD
 quark chemical potential, 220, 223
 quark condensate, 75, 244
 quark-counting rule, 203, 206
 quark–gluon plasma, 213, 217, 218, 244
 degeneracy factors, 217
 Stefan–Boltzmann limit, 218
 quark matter, 238
 three-flavor constraint, 227
 two-flavor constraint, 227
 quark phase, 248
 quarks, 44, 210
 baryon number, 210
 charges, 211
 masses, 211

Index

quasars, 117
 quasi-bound state, 181

r-process nucleosynthesis, 265
 radial oscillations, 189
 relativistic degrees of freedom, 217
 Relativistic Heavy-Ion Collider (RHIC), 245
 relativistic hydrodynamics, 27
 relativistic limit, 52, 54
 relativistic mean-field model, 81, 158, 185
 renormalization scale, 229, 230
 resonances, 195
 Rhoades, Clifford E. Jr., 78
 Rhoades–Ruffini mass limit, 78, 79, 260, 262
 Ricci scalar, 28
 Ricci tensor, 18, 20
 Riemann curvature tensor, 18
 rotating radio-transients, 122
 rotation-powered neutron star, 120
 Ruffini, Remo, 78, 90

Σ -hyperon, 195, 199
 Σ -potential, 202
 scalar potential of nucleons, 177
 scaling relations, 73
 scattering length, 182
 Schwarzschild, Karl, 3
 Schwarzschild factor, 31
 Schwarzschild metric, 21
 Schwarzschild radius, 3, 7, 21
 selfbound star, 76–78, 262, 290
 sequence of nuclei, 155, 158, 159
 Shapiro time delay, 141
 shell effects, 160
 shell model, 201
 singularity, 22
 Sirius B, 92, 113, 114
 Skyrme, Tony H. R., 149, 157
 Skyrme model, 157, 185
 slope parameter, 180, 184
 soft equation of state, 178
 soft gamma-ray repeaters, 122
 solid crust, 103
 soliton, 90
 space-like, 13
 space-like vector, 23
 spectral line, 113, 140
 speed of sound, 57, 59, 91, 118, 286
 standard of time, 120
 star quake, 132
 Stefan–Boltzmann law, 112
 Stefan–Boltzmann limit, 216, 217, 219
 Stein 2051 B, 113
 stellar evolution, 5, 110
 stellar mass black holes, 3, 5
 strange quark, 195, 210, 235, 236
 strange stars, 228
 strangelets, 226, 228

- strangeness, 195, 248
 strong equivalence principle, 12, 232
 strong interactions, 43, 85
 Sturm–Liouville eigenvalue equation, 189
 superfluid vortices, 166
 supermassive black holes, 3, 5
 supernova of AD 1054, 148
 surface energy, 250
 surface gravity, 1, 3, 112
 surface temperature, 113
 surface tension, 251, 262
 surface term, 157
 Sutherland, Peter, 150
 symmetric nuclear matter, 173
 symmetry coefficient, 180, 184
 symmetry energy, 157, 179
- tau lepton, 194
 Terzan 5, 121
 test of general relativity, 145
 tetraquarks, 209
 thermal energy, 107
 thermodynamic consistency, 40, 59
 thermodynamic equilibrium, 246
 thermodynamic limit, 40
 thickness of an outer layer, 105
 Thorne, Kip S., 149
 thought experiment, 10
 three-body interactions, 183
 time-like, 13
 time-like vector, 23
 time to merge, 281
 Titan, 289
 Toimela, Tuomo, 229
 Tolman, Richard C., 34, 148
 Tolman–Oppenheimer–Volkoff equation, 33, 62, 63, 148, 286
 dimensionless, 72
 top quark, 210
 torsion free, 18
 TOV equation, *see* Tolman–Oppenheimer–Volkoff equation
 transverse-traceless gauge, 268, 270, 272, 273, 277
 triple point, 245
 triple pulsar systems, 121
 TT gauge, *see* transverse-traceless gauge
- ultimate energy density, 80
 ultra-relativistic limit, 47, 53, 54
- unitary Fermi gas, 182, 184
 up quark, 210
- vacuum energy density, 213, 224
 vacuum pressure, 213, 224
 Valknut, 179
 Vautherin, Dominique, 168
 vector potential of nucleons, 177
 Vela pulsar, 129, 130, 278
 Very Large Telescope VLT, 140
 Virgo, 264, 269
 Virgo cluster, 275
 virial theorem, 271
 visual binary, 113
 Volkoff, George M., 34, 63, 148
 volume term, 157
 vortices of the neutron superfluid, 132
- Wakano, Masami, 149
 Walecka, John D., 158
 wave equation, 267
 weak equilibrium, 194, 221, 222, 235
 weak equivalence principle, 9
 weak interactions, 210
 weak reaction, 42
 Wheeler, John A., 5, 89, 148, 253
 white dwarf, 252
 atmosphere, 103
 iron white dwarf, 115
 mass, 113
 maximum mass, 70, 100, 186
 ocean, 109
 radius, 71, 113
 spectral types, 111
 surface temperature, 107
 thickness of the atmosphere, 106
 Wigner, Eugene, 153
 Wigner–Seitz cell, 101, 151
 Witten, Eduard, 226
 worldline, 22
- Ξ -hyperon, 195
 Ξ -potential, 202
 X-ray binaries, 122
- ZAMS mass, 5
 Zel’dovich, Yakov B., 76
 Zel’dovich equation of state, 76–78, 260
 Zwicky, Fritz, 4, 147