

Index

- Action at a distance, 45, 96, 99, 127, 172, 176, 178–179
- Aharonov, Yakir, 129
- Aharonov-Bohm effect, 47, 96
- Albert, David, 13, 37, 95, 166, 287
- Algebra
- Galilean, 273, 299, 310
 - Heisenberg, 298
 - non-commutative, 74, 155, 367
 - of observables, 153, 298, 307–310, 348, 353–354, 356, 361, 364, 366, 374
 - von Neumann, 22
- Algebraic approach to quantum mechanics, 34, 43, 47, 348, 353, 355–356
- Allori, Valia, 15, 166, 178, 228
- Araújo, Mateus, 59
- Arenhart, Jonas, 3, 185
- Arnold, Barry, 323
- Arrow of time, 282
- Auyang, Sunny, 279
- Bacciagaluppi, Guido, 39, 279
- Bader, Richard, 384–385
- Baker, David, 279
- Ballentine, Leslie, 247, 283, 288, 290
- Barnum, Howard, 348
- Bauer, Edmond, 52–57
- Beables, 9–12, 14, 22–25, 131, 172
- Bedingham, Daniel, 25, 28
- Bell, John, 74, 77, 79–80, 86, 126, 133, 165, 167, 171–172, 175, 181, 222, 229, 247
- Bell's
- experiment, 247, 249, 251, 262
 - inequalities, 247–250, 252, 255–256, 260
 - theorem, 75, 124, 127, 129
- Bellomo, Guido, 4, 323
- Benatti, Fabio, 13, 15, 25
- Big Bell Test, 260
- Bohm, David, 77, 81, 83, 124, 126, 129, 133, 135, 159, 161, 231
- Bohmian
- mechanics, 71
 - theory, 78, 90–91, 99, 241
- Bohr, Niels, 52–53, 71, 73, 75–76, 83, 93, 121–123, 130, 133, 135, 154–160, 245, 249, 360–361
- Born Rule, 65, 97, 104, 107–108, 111–112, 170, 174, 297, 354
- Born, Max, 83, 279
- Born-Oppenheimer approximation, 38, 382
- Born-Vaidman rule, 101–103
- Bosyk, Gustavo, 4, 323, 333
- Boyle, Robert, 346
- Brown, Harvey, 39, 126–127, 279–281
- Brun, Todd, 21
- Bub, Jeffrey, 33, 60, 62–63, 136, 281, 387
- Bueno, Otávio, 3, 185
- Buonomano, Vincent, 248
- Butterfield, Jeremy, 23
- Callender, Craig, 136, 287
- Cantor, Georg, 199
- Carnap, Rudolf, 135, 154, 157–159
- Carroll, Sean, 103, 122, 134–135, 142–143
- Cartwright, Nancy, 123
- Casimir operators, 40–42, 274, 281, 291
- Cassirer, Ernst, 155–158
- Cauchy surfaces, 16–17, 19–22, 26–27
- Causation, 169, 175
- Chakravartty, Anjan, 150–151
- Chaos, 256, 317–318
- Chen, Eddy K., 158
- Chirality, 379–381, 383–385, 389
- Church, Alonzo, 198
- Clarke, Samuel, 179
- Classical
- configuration space, 164, 166, 170–171
 - limit, 42, 68, 82, 205, 214, 216–220, 360–362, 364–365, 370, 373–375
 - logic, 72, 188, 196, 199, 202–203, 235, 362–364, 366, 374–375

- Classical (cont.)
 mechanics, 71, 76–77, 81–82, 89, 93, 108, 130, 191, 226, 236–237, 239, 242, 275, 278, 280, 283, 346, 363
 physics, 11, 67, 73, 76, 81, 94, 96, 137–139, 158, 177, 205, 235–237
 statistical mechanics, 89, 236–237
 statistics, 209, 214
 universe, 237
 variables, 76–77, 83
- Clifton, Rob, 14
- Collapse
 hypothesis, 385–386
 of the wave function, 87–88, 97, 225–227, 233
 relativistic, 9, 16, 20, 22, 24, 26
 theories, 9–10, 13, 15–16, 20, 22, 25, 95, 100, 104, 125, 165–167, 173–174, 224, 228
- Collier, John, 179
- Contextuality, 32, 44, 75–76, 279, 388
- Correlations, 36–37, 45, 53, 63, 94, 168, 175, 237–239, 245, 247, 262, 315–316, 329, 334, 336, 339, 346–347
- Costa de Beauregard, Oliver, 286
- Cramer, John, 220
- Cushing, James, 124, 126, 128
- d’Espagnat, Bernard, 387
- Dalton, John, 346
- de Broglie, Louis, 80, 124, 126, 229, 231
- Decision theory, 103
- Decoherence
 environment-induced, 345–346
 relativity of, 353
 self-induced, 375
 top-down, closed-system approach to, 346
- Democritus, 261
- Deutsch, David, 103, 121, 129
- Dieks, Dennis, 2, 51
- Diosi, Lajos, 95
- Dirac, Paul, 124, 133, 135, 157, 362, 379, 382
- Discernibility, 187, 192
- Distinguishability, 205, 209, 215, 219–220, 228, 296
- Distribution
 Bose-Einstein, 186, 209, 213, 373
 equilibrium, 83, 85
 Fermi-Dirac, 186, 209, 213, 217, 373
 flash, 238
 Maxwell-Boltzmann, 208–210, 212, 216, 219, 373
 Planck, 210
 Poisson, 226
 Rayleigh-Jeans, 209
- Dürr, Detlef, 166
- Dynamics
 collapse, 21, 167, 227, 230, 232
 deterministic, 242
 Markovian, 16, 18
 nonlinear, 16
- Earman, John, 271, 347
- Egg, Matthias, 229
- Eigenstate-eigenvalue link, 9, 13–15, 23, 153, 280, 387
- Einstein, Albert, 45, 77, 90, 121, 123, 150, 164, 168, 176–178, 219–220, 229, 245–247, 249, 263
- Electron density, 384–385
- Ensemble
 canonical, 211, 214
 grand canonical, 212, 214
- Entanglement
 as a relationship between algebras of observables, 349
 generalization of, 348
 relativity of, 348
- Entropy
 Burg, 327
 quantum, 333
 Rényi, 327
 Shannon, 327, 330, 334, 336, 339
 Tsallis, 327
 von Neumann, 330
- Ergodicity, 245, 248–249, 255–256, 259–261
- Esfeld, Michael, 3, 136, 168, 222
- Euclid, 294
- Everett, Hugh, 54, 126, 133, 135, 161, 239
- Experiment
 Aspect, 127
 double-slit, 114–115
 EPR, 125, 219
 loophole-free, 245, 248–249, 255, 257
 noninteracting, 44
 Stern-Gerlach, 38, 84, 86, 125, 170, 222
- Faye, Jan, 154
- Feynman, Richard, 72, 77, 180, 362
- Finkelstein, Jerry, 21
- Fleming, Gordon, 23
- Folse, Henry, 121
- Forman, Paul, 124, 126
- Fortin, Sebastian, 4, 345, 360, 379
- Frauchiger, Daniela, 58–60, 63, 65
- French, Steven, 193–194, 196, 206, 208, 220
- Frigg, Roman, 145
- Fuchs, Christopher, 136
- Gadella, Manuel, 4, 360
- Galilean
 covariance, 277, 279
 invariance, 291
 transformations, 272, 278, 280, 282, 289, 300
- Galileo Galilei, 71, 245
- Galois, Évariste, 270
- Gamow vectors, 367–369, 374
- Gasiorowicz, Stephen, 285
- Gell-Mann, Murray, 107
- Generalized contexts, 107, 112
- Ghirardi, GianCarlo, 9, 13, 15, 22–23, 25, 95, 226

- Girardeau, Marvin, 316
 Gisin, Nicolas, 16, 18
 Gleason, Andrew, 75
 Goethe, Johann, 155
 Goldstein, Sheldon, 15, 136, 166, 247
 Grassi, Renata, 9, 13, 15, 22–23, 25
 Griffiths, Robert, 55, 107
 Group
 Galilean, 34, 39–42, 269, 272–274, 276–279, 281–282, 284, 286, 288, 291, 295, 310, 312
 Lie, 272
 maximal kinematic, 305, 314
 Poincaré, 42, 282, 291, 295
 Schrödinger, 35
 GRW
 flash theory (GRWf), 230, 233, 235, 238, 240–241
 matter density theory (GRWm), 227, 229, 232–233, 235, 238, 240
 theory, 9, 53, 161, 165, 173, 220, 226–230
 Guiding equation, 78–80, 82–84, 86, 231–232, 234, 238, 241
- Haag, Rudolf, 297
 Hacking, Ian, 123
 Haeceity, 193–197, 200
 Halvorson, Hans, 3, 133, 145
 Hamilton, William, 247
 Hamiltonian
 effective, 372
 non-Hermitian, 368, 372
 Harshman, Nathan, 4, 294
 Hartle, James, 107
 Healey, Richard, 136, 140–141, 159–160
 Hegel, Georg W. Friedrich, 155
 Heisenberg, Werner, 57, 133, 135, 157, 185, 337
 Hendry, Robin, 383
 Hettema, Hinne, 384
 Hidden variables, 75, 78, 87, 123–124, 165–166, 171, 174, 195, 200, 251, 253, 255, 260
 Hnilo, Alejandro, 4, 245
 Holik, Federico, 4, 360
 Howard, Don, 164, 168
 Huggett, Nick, 205, 207–208, 211, 214
 Humeanism, 169, 195, 233, 236
 Hund paradox, 379, 381, 383, 386–390
 Hund, Friedrich, 380
- Improper mixture, 56, 387
 Indiscernibility, 187–188, 197–198, 203
 Indistinguishability, 44–46, 198, 203, 214, 312, 315
 Individuality
 non-, 186, 188, 191, 193–196
 transcendental, 193, 208
 Inequality
 Clauser-Horne (CH), 251
 Clauser-Horne inequality (CH), 250
 Clauser-Horne-Shimony-Holt (CHSH), 250
 Eberhardt's, 250
 Mermin's, 255
 Instrumentalism, 122, 129, 233
 Interpretation of quantum mechanics
 atomic modal, 346
 Bohr's, 85
 consistent-histories, 55
 Copenhagen, 72, 77, 83, 121–122, 133, 245, 247
 de Broglie-Bohm pilot-wave, 122, 281
 Everett, 54, 122, 134, 173–174
 many worlds (MWI), 59, 68, 98–99, 101–104, 126, 165–167, 224
 modal, 32–33, 36, 54, 57, 234, 280–281
 modal-Casimir, 41
 modal-Hamiltonian (MHI), 33–34, 39–40, 46, 54, 281, 356, 388
 perspectival, 59
 QBist (quantum Bayesian), 141, 160
 relational, 55, 57
 statistical, 247–248, 262
 transactional, 220
 Invariance
 dynamical, 304, 308, 313, 317
 Galilei, 41, 269
 Parity, 389
 Poincaré, 42
 time-reversal, 278, 282, 286–288, 290–291
 Irreducible representations (irreps), 40, 295, 347
 Ismael, Jenann, 175
- Jaimes Arriaga, Jesús, 4, 379
 Jaynes, Edwin, 245
- Kant, Immanuel, 124, 155, 379
 Kastner, Ruth, 3, 205
 Kelvin, Lord, 93–94, 96
 Kent, Adrian, 17
 Kepler, Johannes, 294
 Klein, Felix, 279
 Kochen, Simon, 75, 234
 Krause, Décio, 3, 185, 193–194, 196
- Ladyman, James, 3, 121, 179
 Lakatos, Imre, 126, 130
 Landau, Lev, 76
 Lange, Marc, 173
 Laplace, Pierre-Simon, 93, 135
 Laplace's demon, 237
 Lattice
 Boolean, 108, 360, 363
 distributive, 108, 111–112, 363, 365
 orthocomplemented, 108, 111–113, 116, 363–364

396

Laue, Hans, 288
 Laura, Roberto, 2, 107
 Leegwater, Gijs, 65
 Leggett, Anthony, 387
 Leibniz law (principle), 198, 200, 203, 205
 Leibniz, Wilhelm, 179
 Lewis, David, 100
 Lewis, Davis, 205
 Lewis, Peter, 167, 176
 Lieb, Elliott, 316
 Lifshitz, Evgeny, 76
 Liniger, Werner, 316
 Lo, Hoi-Kwong, 335
 Loewer, Barry, 13, 37, 169
 Lombardi, Olimpia, 2, 4, 32, 269, 345
 London, Fritz, 52–57
 López, Cristian, 4, 269
 Lorenz, Max, 323
 Losada, Marcelo, 2, 4, 107, 360

Mach-Zehnder interferometer, 116, 309
 Majorization, 323
 Marshall, Albert, 323
 Martínez González, Juan Camilo, 4, 379
 Mass density, 13, 15, 22, 25
 Matter density
 field, 226–229, 232, 235, 238
 ontology, 25, 167, 229
 Maudlin, Tim, 21, 95, 121, 130, 220, 223–224, 230, 234, 239
 Maxwell equations, 94, 128, 156, 158, 261, 277
 Measurement
 as a symmetry breaking process, 33, 39, 390
 determinate outcomes of, 223
 frequency, 36
 reliable, 37
 single, 36–37, 246, 385
 von Neumann model of, 36–38, 55
 Mermin, David, 21, 180, 254
 Mill, John Stuart, 123
 Minkowski spacetime, 10, 16, 28, 64, 66
 Molecular
 chemistry, 38, 380, 382
 structure, 379–380, 382–385, 390
 Møller, Christian, 155
 Monton, Bradley, 14
 Motion reversal, 290–291
 Mott, Nevill Francis, 124
 Muller, Fred, 192
 Musgrave, Alan, 126
 Myrvold, Wayne, 2, 9, 65, 67, 168, 173, 176

Newton laws, 94
 Newton, Isaac, 71, 178–179, 346
 Ney, Alyssa, 3, 136, 164–165
 Nguyen, James, 145
 Nielsen, Michael, 323, 335
 No-go theorems, 43, 65–66, 123

Index

Noncommutativity, 73
 Nonlocality, 45, 74, 80, 90, 222, 229, 232, 238–239
 Nonseparability, 214
 North, Jill, 282, 287
 Nozick, Robert, 279

Ohanian, Hans, 270
 Olkin, Ingram, 323
 Omnès, Roland, 107
 Ontology
 distributional, 9–10
 of properties, 43, 46
 particle, 159, 222, 226, 231, 233, 240
 primitive, 15, 91, 166–167, 178, 233, 235–236
 Optical isomerism, 38, 380, 386

Parmenides, 261
 Particles
 Bohmian, 97–98, 234
 Bohmian Dirac sea of, 241
 Dirac sea of, 241–242
 identical, 44–45, 78, 304–305, 313, 316, 319
 indistinguishable, 311, 314–317
 individual, 167, 222, 226
 numerical difference of, 191–192
 point, 186, 225–226, 231–232, 239, 241
 Pauli, Wolfgang, 122
 Pearle, Philip, 9, 14, 22, 24, 28, 95
 Peirce, Charles Sanders, 124
 Penrose, Roger, 95, 133
 Peres, Asher, 136
 Perspectivalism, 51, 57–59, 61, 64, 67–68
 Picture/representation
 Heisenberg, 90, 108, 110–113, 127, 361, 365, 374
 interaction, 17
 Schrödinger, 111
 Tomonaga–Schwinger, 17, 20
 Planck constant, 79, 360–361, 374
 Plato, 294
 Popescu, Sandu, 335
 Popper, Karl, 126, 261
 Positive-operator-valued measures, 86
 Principle
 of compositionality, 202
 of correspondence, 246
 of identity of indiscernibles, 191
 of impenetrability, 191
 of individuality, 45, 189, 191–192
 of local causality, 172
 of metaphysical continuity, 10–11, 14
 of superposition, 246, 261, 263
 of uncertainty, 78, 323–324, 337–339
 Pauli exclusion, 213
 Projection postulate, 161, 219, 385
 Properties
 atomic, 108–109, 111–112
 bundles of, 43–44, 46, 356
 case-, 43, 45

- contrary, 107, 113, 116
 definite, 65
 elementary, 360–362
 natural physical, 148–149
 possible, 44, 46
 relational, 57–58, 280
 type-, 43, 45
- Quantum**
 chemistry, 128, 380, 382, 384, 389
 computation, 72, 129, 345
 information, 72, 86, 297, 324, 332, 336, 339, 366
 noise, 366
 potential, 81–82
 statistics, 45, 78, 205, 207, 209–211, 214, 373
 Quantum field theory, 11, 21, 42, 47, 73, 78, 90, 128, 225, 239, 242, 279, 282, 291, 295
 Quantum Theory of Atoms in Molecules (QTAiM), 384–385
 Quasi-set theory, 200
 Quine, Willard V. O., 157
- Racah, Giulio, 286
 Randomness, 78, 83–84, 87, 100, 124, 249, 256, 259, 318
- Realism**
 about the quantum state, 135, 159
 entity, 123, 129
 local, 247, 251
 metaphysical, 129
 ontic structural, 168
 scientific, 72, 121–122, 124–125, 127–130, 143, 149
 spacetime state, 151, 168
- Redhead, Michael, 206, 208, 220
 Reichenbach, Hans, 145
- Relativity**
 general, 150, 185, 201, 228
 special, 64, 66, 96, 176
- Renner, Renato, 58–60, 63, 65
 Rigged Hilbert space, 301, 366, 368
 Rimini, Alberto, 226
 Roberts, Bryan, 283
 Ross, Don, 179
 Rovelli, Carlo, 55, 57, 135, 141, 160
 Ruffini, Remo, 270
- Sachs, Robert, 285
 Sakurai, Jun, 285, 287, 290
 Saunders, Simon, 126, 134, 136, 142, 192
 Scerri, Eric, 386
 Schaffer, Jonathan, 175
 Schlosshauer, Maximilian, 350
 Schmidt decomposition, 330–331
 Schrödinger equation
 covariance of the, 274–277
 invariance of the, 41, 269–270, 275–276
- Schrödinger, Erwin, 72, 80, 83, 186–191, 193–196, 201, 261, 331
 Schrödinger's cat, 72, 88, 223, 232
 Schur, Issai, 323, 326, 328
 Schur-concavity, 326, 333
 Sebens, Charles, 103
 Self-induced decoherence, 371
 Semi-group, 19
 Shimony, Abner, 13, 171
 Signalling, 16, 18–19
 Spacetime
 Galilean, 16, 127
 globally hyperbolic, 16
 relativistic, 10, 16–17, 20
 Specker, Ernst, 75, 234
 Spontaneous localization, 9, 227, 229–230
 Spurrett, Don, 179
 Standard model, 11, 128, 201, 240–241, 297, 346
- State**
 actual, 54, 137
 Bell, 254, 334
 entangled, 16, 18, 45, 51, 53–54, 62, 89, 99, 170, 187, 223, 251, 256–257, 261, 330, 335–336, 347, 349
 extrinsic, 20–22
 GHZ, 253–255
 perspectival, 56
 potential, 137
 reduced, 12, 20–22, 331, 334–335, 345, 350–352, 386–387
 relational, 56
- Suárez, Mauricio, 39, 279
 Sudbery, Anthony, 59
 Superselection rules, 304, 337
 Symmetrization, 46, 214, 219, 317
Symmetry
 abelian, 302
 dynamic, 300, 305
 Galilean, 79, 281, 299
 gauge, 42
 group of, 40, 295, 299
 kinematic, 300, 304–305, 313–315, 317
 of particle permutations, 304
 of the Hamiltonian, 35, 38, 296, 388
 permutation, 103, 188, 192
 Poincaré, 299
 rotational, 35, 299, 304
 space-time, 299
 SU(2), 295
- Tails problem, 13
 Tappenden, Paul, 103
 Tarski, Alfred, 44
 Teller, Paul, 168
 Tensor product structure, 34, 306–311, 313–316, 348, 353
- Theorem**
 Birkhoff's, 326
 Ehrenfest, 362

398

Theorem (cont.)

- equipartition, 215–217
- Horn's, 328
- Kochen-Specker, 41, 45, 139, 279, 388
- Schrödinger, 329, 333
- Schur's, 331
- Uhlmann's, 324
- Zanardi's, 309
- Timpson, Christopher, 142–143, 149, 151–153, 158, 168
- Tumulka, Roderich, 25, 166, 230
- Typicality measure, 231, 236–237, 241–242
- Uncertainty relations, 52, 123, 130, 215–216, 226, 237, 240, 324, 337–339, 372
- Urelemente, 199
- Vaidman, Lev, 2, 93, 135, 253
- van Fraassen, Bas, 32, 129, 149, 151
- Vanni, Leonardo, 2, 107
- von Helmholtz, Hermann, 155
- von Neumann, John, 52–54, 56, 75, 95, 122
- Wallace, David, 103, 134, 136, 142–143, 148–149, 151–153, 158, 161, 168
- Watanabe, Satoshi, 286

Index

Wave function

- as a field on configuration space, 136
- as a mere calculational device, 140
- as a multi-field on physical space, 136
- as an abstract mathematical object, 143
- conditional, 85, 88
- realism, 136, 151, 158
- representational status of the, 157
- Weber, Tullio, 226
- Weihs, Gregor, 259
- Weyl, Hermann, 187–188, 191–192, 200, 279
- Wheeler, John, 121
- Wigner, Eugene, 287–290, 295, 299
- Wigner's friend, 55, 57–58, 65, 67
- Wilson, Jessica, 175
- Wiseman, Howard, 171–172
- Yang, Chen Ning, 316
- Zanardi, Paolo, 297, 308, 310, 315
- Zanghí, Nino, 2, 71, 136, 166
- Zeeman effect, 38
- Zeh, Heinz-Dieter, 371
- Zeilinger, Anton, 121
- Zurek, Wojciech, 349, 353, 355, 371