

Contents

1	Scientific Realism	1
1.1	Empirical Knowledge and Metaphysics	4
1.2	More or Less Empiricist Demarcations	11
1.3	The Real and the Actual	17
1.4	Realism and Quantum Theory	25
1.5	The Metaphysics of Physics	31
1.6	Towards a Realism of Properties	38
2	Extending Physical Reality	41
2.1	Introducing Physical Quantities	43
2.2	Idealization and the Experimental Method	48
2.3	Discovery or Manufacture?	53
2.4	Phenomena and Their Causes	60
2.5	Observation Generalized	65
2.6	The Empirical Reality of Physics	71
3	Particle Observation and Measurement	77
3.1	Two Particle Concepts	80
3.2	Evidence for a Particle: Two Case Studies	83
3.2.1	The Electron	84
3.2.2	The Photon	88
3.3	Theorizing the Observations	92
3.3.1	Position Measurement	94
3.3.2	Particle Tracks	96
3.3.3	Scattering Events	101
3.3.4	Resonances	105
3.4	The Track of the Positron	110
3.5	Particle Identification and Quantum Electrodynamics	114
3.6	Are There Subatomic Particles?	119
4	Probing Subatomic Structure	125
4.1	Scattering Experiments	127
4.2	Rutherford Scattering and Scale Invariance	132
4.3	Pointlikeness in the Quantum Domain	136
4.3.1	Classical Form Factors	138

4.3.2	Relativistic Generalizations	142
4.4	A Chain of Models	148
4.5	Analogy with the Optical Microscope	153
4.6	Looking Into The Atom	158
5	Measurement and the Unity of Physics	161
5.1	Incommensurability and Measurement	163
5.2	A Heterogeneous Measurement Theory	169
5.3	Particle Tracks	174
5.3.1	Mott's Prediction of Classical Tracks	175
5.3.2	Bethe's Calculation of Energy Loss	178
5.3.3	How the Classical Picture Breaks Down	183
5.3.4	Data Analysis in Scattering Experiments	185
5.4	Building Bridges: Unifying Principles	187
5.4.1	Bohr's Correspondence Principle	188
5.4.2	Correspondence Generalized	190
5.4.3	Other Unifying Principles	194
5.5	The Scales of Physical Quantities	198
5.6	Questions of Semantic Consistency	202
6	Metamorphoses of the Particle Concept	209
6.1	Classical Particles	210
6.2	The Shift to Quantum Particles	213
6.2.1	Matter Waves	215
6.2.2	Light Quanta	217
6.3	The Operational Particle Concept	220
6.4	More Quantum Particles	222
6.4.1	Field Quanta	224
6.4.2	The Group Theoretical Definition	229
6.4.3	Virtual Particles	233
6.4.4	Quasi-Particles	238
6.5	The Parts of Matter	246
6.5.1	Matter Constituents Generalized	246
6.5.2	The Quark Model	250
6.6	What Kinds of Particles Remain?	257
7	Wave-Particle Duality	265
7.1	Light Particles and Matter Waves	267
7.2	Wave-Particle Duality in Quantum Mechanics	268
7.2.1	Born's Probability Waves	269
7.2.2	Bohr's Complementarity View	272
7.2.3	Heisenberg's Analogies	277
7.3	Prepare Waves, Detect Particles	278
7.3.1	What Makes the Difference	280
7.3.2	Two Lasers, One Photon	284

7.3.3	Polarized Photons	285
7.4	The Double Slit Reconsidered	289
7.4.1	How to Store and Erase Path Information	291
7.4.2	Complementarity Without Uncertainty?	296
7.4.3	Duality Relations	301
7.5	Recent Which-Way Experiments	305
7.6	The Causes of the Phenomena	316
8	Subatomic Reality	321
8.1	Scientific Realism Reconsidered	322
8.2	The Meaning of Quantum Concepts	324
8.3	The Mereological Particle Concept	326
8.4	The Causal Particle Concept	329
8.5	Wave-Particle Duality	330
8.6	Subatomic Reality: A Critical View	334

Appendices

A	Measurement Theory	343
A.1	Empirical Relational Structures	343
A.2	Physical Quantities	344
A.3	The Archimedean Axiom	345
A.4	The Metaphysics of Measurement	345
B	The <i>II</i>-Theorem of Dimensional Analysis	349
C	The Effective Cross-Section	351
D	Dimensional Analysis of Rutherford Scattering	355
E	Mereology	357
E.1	Axioms of Mereology	357
E.2	Mereology and Physics	358
E.3	Matter Constituents	360
	References	363
	Name Index	383