

Contents

1	Introduction	1
----------	---------------------------	----------

Part I What Is Quantum Electrodynamics?

2	Relativistic Covariance	7
2.1	The Lorentz Group	7
2.2	Representations	9
2.3	Covariant Fields	16
3	Electrodynamics as a Classical Field Theory	19
4	The Basic Principles of Relativistic Quantum Field Theory	25
4.1	The Wightman Axioms	25
4.2	The Wightman Functions	32
5	Free Fields	39
5.1	The Hermitian Scalar Field	39
	Relation to the Canonical Formalism	45
5.2	Dirac Spinors	47
5.3	The Electromagnetic Field	53
5.4	The Functions Δ_+ , D_+ , and Related Functions	61
6	An Outline of Interacting QED	67
6.1	General Description	67
6.2	Solving the Field Equations	73
6.3	Renormalization and the UV Problem	75
7	The Electric Charges	85

Part II Perturbation Theory

8	The Program of Perturbation Theory	95
8.1	The Problem	95
	(a) Equations of Motion	95
	(b) W-Properties	97
	(c) Renormalization Conditions	97
8.2	Perturbation Theory	98
8.3	Uniqueness	100
8.4	Time-Ordered Products	103
9	Unrenormalized Solution	109
9.1	Generalities	109
9.2	Special Examples in Low Orders	110
9.3	The General Solution	115
	Configuration Space	115
	Momentum Space	120
9.4	Verifications	123
9.5	Current Conservation and the Charge Identity	131
10	Renormalization and the UV Problem	135
10.1	Low Orders	135
	The Photon 2-Point Function	135
	The Electron 2-Point Function	142
	The Vertex Function	147
10.2	The General Case	151
10.3	Renormalization in Configuration Space	156
11	The IR Problem for Wightman Functions	165
11.1	The Problem	165
11.2	The Solution	167
11.3	The W-Properties and Other Conditions	176
	The W-Properties	176
	The Charge Identity	178
	Smoothness Conditions	180
12	Physical States	187
12.1	The General Strategy	187
12.2	Unrenormalized Perturbation Theory	192
12.3	The UV Problem	197
12.4	The IR Problem and the Final Verifications	201

Part III Particles and Their Reactions

13 The Standard View 213
 13.1 Massive Theories 214
 13.2 The IR Problem 217

14 Particle Probes 221
 14.1 Mathematical Preliminaries 222
 14.2 Free Particles 229

15 Interacting Particles 239
 15.1 Probes for Interacting Particles 239
 15.2 IR Cancellations 246
 Proof of Lemma 15.4 259
 Proof of Theorems 15.1–3 265
 15.3 Photons 272
 Derivation of the Decomposition (15.87) 276

16 Reactions 283
 16.1 Massive Scalar Fields 283
 16.2 Reactions in QED 296
 16.3 Photons 300
 16.4 Electrons 304

17 Cross Sections 321
 17.1 Cross Sections: the Problem 321
 17.2 A Solution 330
 17.3 Compton Scattering, an Example 336

References 347

Index 351