
Contents

Part I Basic Concepts, Introduction to QED, $g - 2$ in a Nutshell, General Properties and Tools

1	Introduction	3
	References	17
2	Quantum Field Theory and Quantum Electrodynamics	23
2.1	Quantum Field Theory Background	23
2.1.1	Concepts, Conventions and Notation	23
2.1.2	C, P, T and CPT	30
2.2	The Origin of Spin	34
2.3	Quantum Electrodynamics	44
2.3.1	Perturbation Expansion, Feynman Rules	46
2.3.2	Transition Matrix-Elements, Particle-Antiparticle Crossing	51
2.3.3	Cross Sections and Decay Rates	53
2.4	Regularization and Renormalization	55
2.4.1	The Structure of the Renormalization Procedure	55
2.4.2	Dimensional Regularization	58
2.5	Tools for the Evaluation of Feynman Integrals	65
2.5.1	$\epsilon = 4 - d$ Expansion, $\epsilon \rightarrow +0$	65
2.5.2	Bogolubov-Schwinger Parametrization	66
2.5.3	Feynman Parametric Representation	67
2.5.4	Euclidean Region, Wick-Rotations	67
2.5.5	The Origin of Analyticity	69
2.5.6	Scalar One-Loop Integrals	72
2.5.7	Tensor Integrals	74
2.6	One-Loop Renormalization	76
2.6.1	The Photon Propagator and the Photon Self-Energy	76
2.6.2	The Electron Self-Energy	86
2.6.3	Charge Renormalization	92

2.6.4	Dyson- and Weinberg-Power-Counting Theorems	100
2.6.5	The Running Charge and the Renormalization Group . .	102
2.6.6	Bremsstrahlung and the Bloch-Nordsieck Prescription . .	112
2.7	Pions in Scalar QED and Vacuum Polarization by Vector Mesons	121
2.8	Note on QCD: The Feynman Rules and the Renormalization Group	125
	References	131
3	Lepton Magnetic Moments: Basics	135
3.1	Equation of Motion for a Lepton in an External Field	135
3.2	Magnetic Moments and Electromagnetic Form Factors	140
3.2.1	Main Features: An Overview	140
3.2.2	The Anomalous Magnetic Moment of the Electron	162
3.2.3	The Anomalous Magnetic Moment of the Muon	166
3.3	Structure of the Electromagnetic Vertex in the SM	168
3.4	Dipole Moments in the Non-Relativistic Limit	172
3.5	Projection Technique	173
3.6	Properties of the Form Factors	179
3.7	Dispersion Relations	181
3.7.1	Dispersion Relations and the Vacuum Polarization	182
3.8	Dispersive Calculation of Feynman Diagrams	190
	References	198

Part II A Detailed Account of the Theory, Outline of Concepts of the Experiment, Status and Perspectives

4	Electromagnetic and Weak Radiative Corrections	207
4.1	$g - 2$ in Quantum Electrodynamics	207
4.1.1	One-Loop QED Contribution	209
4.1.2	Two-Loop QED Contribution	209
4.1.3	Three-Loop QED Contribution	213
4.1.4	Four-Loop QED Contribution	218
4.1.5	Five-Loop QED Contribution	223
4.2	Weak Contributions	224
4.2.1	Weak One-Loop Effects	228
4.2.2	Weak Two-Loop Effects	229
	References	260
5	Hadronic Effects	265
5.1	Vacuum Polarization Effects and e^+e^- Data	266
5.1.1	Integrating the Experimental Data and Estimating the Error	277
5.1.2	The Cross-Section $e^+e^- \rightarrow$ Hadrons	279

5.1.3	$R(s)$ in Perturbative QCD	284
5.1.4	Non-Perturbative Effects, Operator Product Expansion	288
5.2	Leading Hadronic Contribution to $(g - 2)$ of the Muon	291
5.2.1	Addendum I: The Hadronic Contribution to the Running Fine Structure Constant	297
5.2.2	Addendum II: τ Spectral Functions vs. e^+e^- Annihilation Data	298
5.2.3	Digression: Exercises on the Low Energy Contribution	300
5.3	Higher Order Contributions	306
5.4	Hadronic Light-by-Light Scattering	312
5.4.1	Calculating the Hadronic LbL Contribution	316
5.4.2	Sketch on Hadronic Models	318
5.4.3	Pion-pole Contribution	325
5.4.4	The $\pi^0\gamma\gamma$ Transition Form Factor	327
5.4.5	A Summary of Results	339
	References	341
6	The $g - 2$ Experiments	347
6.1	Overview on the Principle of the Experiment	347
6.2	Particle Dynamics	352
6.3	Magnetic Precession for Moving Particles	355
6.3.1	$g - 2$ Experiment and Magic Momentum	358
6.4	Theory: Production and Decay of Muons	362
6.5	Muon $g - 2$ Results	365
6.6	Ground State Hyperfine Structure of Muonium	367
6.7	Single Electron Dynamics and the Electron $g - 2$	369
	References	373
7	Comparison Between Theory and Experiment and Future Perspectives	375
7.1	Experimental Results Confront Standard Theory	375
7.2	New Physics in $g - 2$	381
7.2.1	Anomalous Couplings	392
7.2.2	Supersymmetry	393
7.3	Perspectives for the Future	406
	References	411
	Index	421

<http://www.springer.com/978-3-540-72633-3>

The Anomalous Magnetic Moment of the Muon

Jegerlehner, F.

2008, XIV, 426 p. 172 illus., Hardcover

ISBN: 978-3-540-72633-3