
Contents

<i>Figures and Tables</i>	i
<i>Preface</i>	iii
<i>Acknowledgements</i>	v
<i>Notations and Conventions</i>	vi
I Quantum Field Theory Basics	1
1 Relationship between the equations of motion of ϕ and ϕ_{in}	11
2 Little group elements for massless particles	12
3 S-matrix in terms of ϕ_{in} and ϕ_{out}	15
4 Constraints on the S-matrix from causality	17
5 Landau equations for soft and collinear singularities	22
6 Multi-loop integration in D dimensions	28
7 Weinberg convergence theorem	31
8 Electron anomalous magnetic moment	34
9 Ward-Takahashi identities and Lorentz invariance	38
10 Equivalence principle and Lorentz invariance	41
11 Lee-Nauenberg theorem	43
12 Classical external field approximation	49
13 Subleading soft radiation in scalar QED	54
14 Low-Burnett-Kroll theorem	58
15 Coherent states in Quantum Field Theory	63

16	Running couplings in a two-fields scalar field theory	65
17	Solution of the running equation at two loops	70
II	Functional Methods	72
18	Weyl quantization	78
19	Combinatorial interpretation of the Legendre transform	81
20	Coherent state path integral	85
21	Coherent state path integral (cont.)	88
22	Spin coherent states and Berry phase	92
23	Zeta function regularization of the Klein-Gordon operator	102
24	Casimir zero-point energy	105
25	The Feynman diagrams behind the Casimir energy	109
26	Gross-Neveu model	113
27	D'Hoker-Gagné formula	117
28	Stochastic quantization	120
29	Complex Langevin equation	125
III	Non-Abelian Fields	132
30	Basic $\mathfrak{su}(n)$ identities	139
31	More $\mathfrak{su}(n)$ identities	141
32	More $\mathfrak{su}(n)$ identities (cont.)	142
33	An $\mathfrak{su}(2)$ identity	144
34	Area derivative of a Wilson loop	146
35	Endpoint derivative of a Wilson line	147
36	Makeenko-Migdal loop equation	150
37	Classical non-Abelian particles and Wong equations	153
38	Wong equations from the worldline formalism	156
39	Non-Abelian Stokes theorem	159
40	QED in the 't Hooft-Veltman gauge	164
41	LSZ reduction formula and gauge invariance	169
42	Large N expansion in $SU(N)$ Yang-Mills theory	173
43	Soft radiation and Antenna effects in QCD	177
44	An identity obeyed by on-shell QCD amplitudes	185
45	Low-Burnett-Kroll theorem in QCD	187
46	Globally gauge invariant operators	190
47	Banks-Zaks fixed points	194
48	Instantons and tunneling in quantum mechanics	196
49	Instantons as transitions between pure gauges in Yang-Mills theory	199
50	Vacua of Yang-Mills theory	202

IV Scattering Amplitudes	208
51 Enumeration of tree graphs	215
52 Six-point $---++$ amplitude	217
53 Two spinor-helicity identities	219
54 Auxililary vector dependence of the polarization vectors	221
55 Polarization sum in the spinor-helicity formalism	223
56 Photon decoupling identity	224
57 Scalar-antiscalar-gluons amplitudes	226
58 Color decomposition with a quark-antiquark pair	230
59 Quark-antiquark-gluons amplitudes	233
60 Quark-antiquark-gluons amplitudes (cont.)	237
61 Gluon-gluon scattering in the spinor-helicity framework	242
62 Soft limit of gluon amplitudes	246
63 Collinear limit of gluon amplitudes	251
64 Enumeration of one-loop graphs	256
65 Ultraviolet finiteness of one-loop all-plus amplitudes	262
66 Rationality of one-loop all-plus amplitudes	263
67 One-loop 4-point $++++$ amplitude from generalized unitarity	265
68 One-loop 5-point $++++$ amplitude from generalized unitarity	271
V Lattice, Finite T, Strong Fields	280
69 Banks-Casher relation	287
70 Nielsen-Ninomiya theorem	289
71 Wigner transform of a convolution product	294
72 Center symmetry and deconfinement	297
73 Photon hard thermal loop from classical particles	301
74 Gluon hard thermal loop from colored classical particles	305
75 Landau-Pomeranchuk-Migdal effect	309
76 Microcanonical equilibration in ϕ^4 scalar theory	316
77 Combinatorics of multi-particle production	319
78 Generating functional for particle production	324
79 Correlations in the Schwinger mechanism	328
80 Schwinger mechanism from Bogoliubov transformations	335
81 Unruh effect, Hawking radiation	343
82 Anderson localization	351
83 Scaling theory of Anderson localization	354
<i>Index</i>	357