

CONTENTS

Figures	xi
Series Preface	xv
Preface	xvii
1 INTRODUCTION	
1.1 Charged Particle Beams	1
1.2 Beam Lines and Spectrometers	5
1.3 Physics Considerations	10
1.4 Beam Sources	14
1.5 Magnets	17
2 EQUATIONS OF MOTION AND TRANSFER MATRICES	
2.1 The Vector Differential Equation of Motion	21
2.2 Magnetic Field Expansion	24
2.3 Characteristic Rays and Transfer Matrices	27
2.4 Path Length Differences	32
2.5 Conjugate Variables and Liouville's Theorem	34
2.6 General Solution of the First-Order Equations	36
3 APPLICATIONS TO MAGNETS	
3.1 Quadrupole Magnet	39
3.2 Bending Magnets	42
3.3 Magnetic Systems	44
3.4 Entrance and Exit Face Focusing	46
3.5 Extended Fringe Fields	52

4 QUADRUPOLE SYSTEMS

4.1	Quadrupole Systems	59
4.2	Focal Conditions	61
4.3	Thin Lenses and Principal Planes	63
4.4	A Quadrupole Singlet	66
4.5	A Quadrupole Doublet	68
4.6	A Quadrupole Triplet	73

5 SYSTEMS WITH DISPERSION

5.1	Dispersive Systems	77
5.2	Sector Bending Magnets	78
5.3	General Bending Magnets	82
5.4	Focusing Systems	84
5.5	Momentum Resolution and Achromaticity	87
5.6	A Recombining System	90
5.7	Isochronicity	95

6 THE BEAM ELLIPSE

6.1	Magnet Apertures and Ellipse Representation	99
6.2	Beam Ellipse Transformation	104
6.3	Relation Between Focal and Waist Conditions	108
6.4	Minimum Spot Size	111
6.5	Accelerator Notation	114
6.6	Ellipse Parameters and Characteristic Functions	120

7 SECOND ORDER—EQUATIONS

7.1	Second-Order Transfer Matrices	123
7.2	Vector Differential Equation of Motion	126
7.3	Magnetic Field Expansion	129
7.4	Solution of the Equations of Motion	131
7.5	Second-Order Transverse Matrix Elements	135
7.6	Path-Length Differences	138

8 SECOND ORDER—MAGNETS

8.1	Quadrupoles	145
8.2	Multipole Components in Physical Quadrupoles	148
8.3	Large-Angle Effects in Quadrupoles	153
8.4	Sextupoles	158
8.5	Bending Magnet Edge Fields—Equations	161
8.6	Bending Magnet Edge Fields—Matrix Elements	170

9 SECOND ORDER—SYSTEMS

9.1	Second-Order Coefficients for Systems	175
9.2	High-Energy Approximations	179
9.3	Chromatic Aberrations	184
9.4	Placement of Sextupoles	189
9.5	Second-Order Corrections in a Beam Line	193
9.6	Sextupole Corrections in an Analyzing Spectrometer	198
9.7	The Beam Ellipse	202

10 PERIODIC SYSTEMS AND BEAM MATCHING

10.1	Periodic Systems	207
10.2	Periodic Systems—Dispersion and Chromatic Aberration	214
10.3	Scaling	216
10.4	Antisymmetric Reflection	220
10.5	Flux Collection	224
10.6	Acceptance Matching	228
10.7	A Second-Order Achromat	231
10.8	Interchange of Planes	236

11 POLARIZATION

11.1	What Polarization Is	241
11.2	Covariant Equation of Polarization Precession	244
11.3	Laboratory Equation of Polarization Precession	247
11.4	Effect of Magnets on Polarization	251
11.5	Polarization Precession in Beam Lines	254
11.6	Snakes	257

12 DISTURBANCES

12.1	Magnet Misalignments	261
12.2	Field Regulation Errors	266
12.3	Scattering	268
12.4	Synchrotron Radiation—Classical Theory	272
12.5	Synchrotron Radiation—Quantum Fluctuations	276
12.6	Space Charge	281

Bibliography	287
Index	295