

Contents

Preface to the Third Edition	vii
Preface to the Second Edition	ix
Preface to the First Edition	xiii
Acknowledgement	xv
List of Figures	xxiii
Chapter 1 Toroidal Configuration	1
1.1 INTRODUCTION	1
1.2 GENERAL COORDINATES	6
1.3 BASIS VECTORS, METRIC TENSOR	7
1.4 VECTOR OPERATORS	9
1.5 MAGNETIC FIELD REPRESENTATION	10
1.6 MAGNETIC SURFACES	11
1.7 MAGNETIC SURFACE DESTRUCTION	13
1.8 THE STANDARD MAP	22
1.9 Problems	29
1.10 References	31
Chapter 2 Equilibrium	33
2.1 INTRODUCTION	33
2.2 THE VIRIAL THEOREM	34
2.3 FIELD LINE CURVATURE	35
2.4 GENERAL 3-D EQUILIBRIA	36

2.4.1	Hamada coordinates	40
2.4.2	Boozer coordinates	41
2.4.3	Cylindrical coordinates	42
2.4.4	Zakharov coordinates	42
2.5	STELLARATORS	43
2.6	AXISYMMETRIC EQUILIBRIA	46
2.7	TOKAMAK ORDERING	48
2.8	THE SHAFRANOV EQUILIBRIUM	49
2.9	CYLINDRICAL TOKAMAK EQUILIBRIA	55
2.10	HIGH BETA EQUILIBRIUM	58
2.11	FLUX CONSERVING EQUILIBRIA	60
2.12	EQUILIBRIUM SCALING	61
2.13	EQUILIBRIUM TYPES	62
2.14	STEPPED PRESSURE EQUILIBRIA	63
2.15	Problems	69
2.16	References	70

Chapter 3	Guiding Center Motion	73
3.1	INTRODUCTION	73
3.2	LAGRANGIAN AND HAMILTONIAN FORMULATION	77
3.3	ORBIT TYPES IN AXISYMMETRIC EQUILIBRIA	82
3.4	INTEGRAL INVARIANTS	93
3.5	TOROIDAL PRECESSION	96
3.6	LARGE ASPECT RATIO	98
3.7	DIAMAGNETIC CURRENT	102
3.8	CONFINEMENT OF FUSION ALPHA PARTICLES	104
3.9	MAGNETIC PERTURBATIONS	104
3.9.1	Toroidal field ripple	104
3.9.2	Flute modes	105
3.9.3	Ideal MHD modes	110
3.9.4	Kinetic Poincaré plots	111
3.10	SCATTERING AND ENERGY DIFFUSION	115
3.11	Problems	118
3.12	References	119

Chapter 4	Linear Ideal Modes	121
4.1	INTRODUCTION	121
4.2	PLASMA KINETIC AND POTENTIAL ENERGY	126

4.3	SELF ADJOINTNESS OF THE POTENTIAL ENERGY	127
4.4	THE ENERGY PRINCIPLE	128
4.5	CONVENIENT FORM FOR δW	129
4.6	CYLINDRICAL GEOMETRY ENERGY PRINCIPLE	133
4.7	MHD INSTABILITIES IN LOW β TOKAMAKS	137
4.8	KINK MODE	139
4.9	THE $M = 1$ EXTERNAL KINK	144
4.10	THE INTERNAL KINK MODE	145
4.11	BALLOONING INSTABILITIES	148
4.12	MAGNETIC WELL	154
4.13	BALLOONING, SIMPLE EQUILIBRIA	155
4.14	MERCIER, SUYDAM CRITERIA	158
4.15	BALLOONING EQUATION MODIFICATION	162
4.16	TAE MODES	163
4.17	AXISYMMETRIC MODES	164
4.18	NUMERICAL MHD SPECTRUM	167
4.19	SHAPE AND ASPECT RATIO	168
4.20	Problems	172
4.21	References	173

Chapter 5	Linear Resistive Modes	177
5.1	INTRODUCTION	177
5.2	THE TEARING MODE	182
5.2.1	The tearing mode, $m \neq 1$	191
5.2.2	The $m = 1$ tearing mode	194
5.3	THE SKIN CURRENT PROFILE	201
5.4	TOROIDAL AND SHAPING EFFECTS	202
5.5	THE RESISTIVE SURFACE KINK MODE	204
5.6	OPTIMIZED PROFILES	206
5.7	THE RIPPLING MODE	208
5.8	THE RESISTIVE INTERCHANGE MODE	209
5.9	RESISTIVE BALLOONING	209
5.10	DIAMAGNETIC ROTATION	211
5.11	Problems	215
5.12	References	217

Chapter 6	Mode-Particle Interaction	221
6.1	INTRODUCTION	221

6.2 IDEAL DISPLACEMENT $\vec{\xi}$, α , $\delta\vec{B}$, AND POTENTIAL	226
6.3 RESONANCE	233
6.4 THE FIBONACCI SEQUENCE	236
6.5 LANDAU PHASE MIXING	238
6.6 PHASE VECTOR ROTATION	241
6.7 MODE INDUCED AVALANCHE	246
6.8 MODE-PARTICLE ENERGY TRANSFER	251
6.9 MODE EVOLUTION	253
6.9.1 Frequency determined by equilibrium	253
6.9.2 Frequency determined by particle distribution	257
6.9.3 Calculation of δW_n	276
6.9.4 Monte Carlo evaluation	278
6.10 TAE MODE DRIVE AND SATURATION	280
6.11 TRAPPED PARTICLE RESONANCE	284
6.12 FISHBONE INDUCED LOSS	287
6.13 FISHBONE DESTABILIZATION	289
6.14 THE FISHBONE CYCLE	299
6.15 RESISTIVE KINETIC INTERNAL KINK	302
6.16 STABILIZATION OF THE SAWTOOTH	303
6.17 BALLOONING DESTABILIZATION	308
6.18 ALPHA PARTICLE EFFECTS	309
6.19 Problems	311
6.20 References	312
Chapter 7 Cyclotron Motion	317
7.1 INTRODUCTION	317
7.2 SUB CYCLOTRON HEATING	317
7.3 STOCHASTIC DOMAIN	323
7.4 CYCLOTRON MOTION IN A TOROIDAL SYSTEM	325
7.5 CYCLOTRON AND GUIDING CENTER ANALYSES OF RESONANCE	328
7.6 PROFILE FLATTENING	331
7.7 References	333
Chapter 8 Nonlinear Behavior	335
8.1 INTRODUCTION	335
8.2 THE REDUCED EQUATIONS	339
8.3 NONLINEAR EXTERNAL KINK	342

8.4 VACUUM BUBBLES	345
8.5 NONLINEAR INTERNAL KINK	349
8.6 COMPLETE RESISTIVE RECONNECTION	352
8.7 NONLINEAR TEARING MODE ANALYSIS	352
8.8 SAWTOOTH OSCILLATIONS	360
8.9 DISRUPTIONS	365
8.10 EMPIRICAL LIMITS	370
8.11 THE GREENWALD DENSITY LIMIT	372
8.12 STABILIZATION OF TEARING MODES	374
8.13 Problems	377
8.14 References	378
Chapter 9 Transport	383
9.1 INTRODUCTION	383
9.2 THE DRIFT KINETIC EQUATION	389
9.3 CROSS FIELD DIFFUSION	392
9.4 BOOTSTRAP CURRENT	396
9.5 NEOCLASSICAL TEARING	401
9.6 WARE PINCH	401
9.7 MAGNETIC FIELD RIPPLE TRANSPORT	402
9.8 DIFFUSION IN A STOCHASTIC FIELD	415
9.9 ISLAND INDUCED DIFFUSION	418
9.10 ANOMALOUS TRANSPORT	421
9.11 CONFINEMENT SCALING	426
9.12 NONLOCAL TRANSPORT	428
9.12.1 Determination of the Lévy flight distribution	432
9.12.2 Two fluid Montroll equation	433
9.13 BURN CONTROL	435
9.14 Problems	438
9.15 References	441
Chapter 10 The Lithium Wall Fusion Concept	447
10.1 THE IDEA OF MAGNETIC FUSION	447
10.2 CONFINEMENT REGIME CONTROLLED BY THERMAL CONDUCTION	449
10.3 DIFFUSION BASED CONFINEMENT REGIME	450
10.4 IMPLEMENTATION	452
10.5 ALPHA PARTICLE CONFINEMENT	454

10.6 DIVERTOR PLATES	455
10.7 References	456
Chapter 11 Phase Integral Methods	457
11.1 INTRODUCTION	457
11.2 CONNECTION FORMULAE	460
11.3 CAUSALITY	467
11.4 BOUND STATES – INSTABILITIES	468
11.5 OVERDENSE BARRIER – SCATTERING	472
11.6 UNDERDENSE BARRIER – SCATTERING	476
11.7 EIGENVALUE PROBLEMS	479
11.8 Problems	484
11.9 References	487
Index	489