

Contents

Notation	vii
Acknowledgments	xi
1 Introduction	1
2 Tokamak Evolution	4
3 Concept of Tokamaks and their Status	9
3.1 Nuclear Fusion	9
3.2 Magnetic Confinement	11
3.3 Charged Particles and Fields	16
3.4 Elementary Plasma Dynamics	20
3.5 Plasma Equilibrium	24
3.6 Plasma Stability	30
3.7 Operational Limits	35
3.8 Plasma as a Complex System	37
3.9 Physics of Confinement	40
3.10 Edge Plasma	47
3.11 Current Drive	49
3.12 Tokamak Reactor	54
4 Plasma Equilibrium	57
5 Plasma Stability	64
5.1 Kink Instability	65
5.2 Tearing Instability	73
5.3 Flute Instability	77
5.4 The Ballooning Instability	81
5.5 Internal Kink Mode	85
5.6 Drift Instabilities	85

6 Plasma as a Complex System	90
6.1 Dimensional Approach	92
6.2 Dimensional Analysis of Tokamaks	95
6.3 Murakami and Hugill Numbers	100
6.4 Dimensional Analysis of Energy Confinement	102
7 Non-linear Plasma Activity	109
7.1 Mirnov Oscillations	109
7.2 Saw-tooth Oscillations	110
7.3 Disruption Instability	114
7.4 Fan Instability	117
7.5 'Fish-bone' Instability	119
7.6 Edge Localized Modes	121
7.7 MARFE	122
8 Plasma Thermal Insulation	124
8.1 Neoclassical Theory of Transport	124
8.2 Bootstrap Current	129
8.3 Confinement Modes	132
8.4 Scalings	143
8.5 Thermal Conductivity, Diffusion and Viscosity	147
9 Plasma Self-organization	151
9.1 Profile Self-consistency	151
9.2 Optimal Profiles	153
9.3 Spontaneous Breakdown of Symmetry	161
9.4 Physics of Transport	177
10 Heating and Current Drive	183
10.1 Ohmic Heating	183
10.2 Lower Hybrid Resonance	184
10.3 Ion-cyclotron Resonance	185
10.4 Electron-cyclotron Resonance	186
10.5 Neutral Injection	188
10.6 Other Schemes of Heating	189
11 The Burning Plasma	191
12 Conclusion	194
References	199
Index	207