

Contents

Preface xi

1

Introduction 3

- 1.1 Historical Perspective 4
- 1.2 Tokamaks 8
- 1.3 Outline of the Book 21
- 1.4 Bibliography 23
- 1.5 References 24

2

The MHD Equations 27

- 2.1 Introduction 27
- 2.2 Magnetic Flux and Faraday's Law 29
- 2.3 Motion of Magnetic Field Lines 32
- 2.4 The $\mathbf{J} \times \mathbf{B}$ Force 36
- 2.5 Conservative Forms of the MHD Equations 37
- 2.6 Effects Neglected by the MHD Model 40
- 2.7 Summary 44
- 2.8 References 45

3

- The Rayleigh-Taylor Instability** 47
- 3.1 Incompressible Hydrodynamic Model 48
 - 3.2 Compressible Hydrodynamic Models 51
 - 3.3 MHD Incompressible Rayleigh-Taylor Instability 54
 - 3.4 Summary 57
 - 3.5 References 58

4

- MHD Equilibrium** 59
- 4.1 Force Balance Equations 59
 - 4.2 Surface Quantities 60
 - 4.3 The q -Value 64
 - 4.4 The Grad-Shafranov Equation 66
 - 4.5 Cylinder with Elongated Cross Section—An Example of Bifurcation 71
 - 4.6 Plasma Squeezed Between Conducting Walls 76
 - 4.7 Tokamak Equilibrium 79
 - 4.8 Summary 86
 - 4.9 References 86

5

- Linearized Equations and the Energy Principle** 89
- 5.1 Linearized Equations 90
 - 5.2 ξ -Form of the Equations 91
 - 5.3 The Energy Principle 93
 - 5.4 Different Forms of the Energy Principle 95
 - 5.5 Methods Used in Linear Stability Analysis 98
 - 5.6 Summary 99
 - 5.7 References 100

6

- Circular Cylinder Instabilities** 102
- 6.1 Equilibrium 103
 - 6.2 Physical Picture of Current Driven Instabilities 104
 - 6.3 The 1-D Eigenvalue Equation 109

6.4 The 1-D Energy Principle	112
6.5 Fixed-Boundary Instabilities	114
6.6 Free-Boundary Instabilities	121
6.7 Summary	123
6.8 References	123

7

Toroidal Instabilities	125
7.1 Flux Coordinates	125
7.2 Mercier Stability Criterion	130
7.3 Applications of the Mercier Criterion	139
7.4 Large-Scale Instabilities in Axisymmetric Tori	142
7.5 Summary	146
7.6 References	146

8

High Beta Tokamaks	149
8.1 Elongated Cross Section	150
8.2 High Beta Instabilities: Surface Current Model	154
8.3 Flux Conserving Tokamaks	163
8.4 Summary	171
8.5 References	173

9

Nonlinear Instability Theory	175
9.1 Nonlinear Methods	176
9.2 Free-Boundary Instabilities	179
9.3 Fixed-Boundary Instabilities	183
9.4 References	188

10

Resistive Instabilities	190
10.1 Magnetic Islands	192
10.2 Growth of the Resistive Tearing Mode	198
10.3 $m=1$ Resistive Tearing Mode	205
10.4 Resistive Interchange Mode	209

10.5 Summary 213

10.6 References 214

11

Comparison Between Theory and Experiment 217

11.1 Sawtooth Oscillations 218

11.2 Mirnov Oscillations 223

11.3 The Disruptive Instability 226

11.4 References 230

Appendix A: Comments on the Questions 233

Appendix B: Glossary 253

Index 257