

CONTENTS

PREFACE	xi
ACKNOWLEDGEMENTS	xii
CHAPTER 1 INTRODUCTION TO SOLAR ACTIVITY (E R Priest)	1
1.1 Some Basic Properties of the Sun	1
1.2 Basic Equations of Magnetohydrodynamics	5
1.2.1 Magnetohydrostatics	8
1.2.2 Waves	10
1.2.3 Instabilities	11
1.3 Sunspots	12
1.4 Prominences	13
1.4.1 Prominence Formation	14
1.4.2 Magnetostatic Support	15
1.5 The Corona	17
1.5.1 Models of the Corona	17
1.5.2 Coronal Heating	18
1.6 Solar Flares	20
1.7 Conclusion	22
References	22
CHAPTER 2 AN INTRODUCTION TO MAGNETOSPHERIC MHD (D J Southwood)	25
2.1 Introduction	25
2.2 Why is There a Magnetosphere?	26
2.3 The Open Magnetosphere Morphology	28
2.4 Momentum Transfer	30
2.5 Magnetospheric Substorms	32
2.6 Magnetohydrodynamic Waves	33
References	35
CHAPTER 3 MAGNETOHYDRODYNAMIC WAVES (B Roberts)	37
3.1 Structuring and Stratification	37
3.2 Waves in a Magnetically Structured Atmosphere	39
3.3 Waves in a Uniform Medium	41
3.3.1 The Alfvén Wave	42
3.3.2 Magnetoacoustic Waves	43
3.4 Waves in Discretely Structured Media	46
3.4.1 Incompressible Medium	47
3.4.2 Compressible Medium	51
3.5 Oscillations in a Low β -Gas	54
3.5.1 Slab Inhomogeneities	54
3.5.2 Cylindrical Inhomogeneities	56
3.5.3 Impulsively Generated Fast Waves	58
3.6 Damped Alfvén Waves	61

3.7	Waves in Stratified Atmospheres	63
3.7.1	Sound Waves	64
3.7.2	The Influence of a Horizontal Magnetic Field	68
3.8	Slender Flux Tubes	70
3.8.1	The Slender Flux Tube Equations : Sausage Modes	71
3.8.2	Pulse Propagation	74
3.8.3	Kink Modes	76
3.8.4	Instabilities in Tubes	76
	References	78
 CHAPTER 4 MHD INSTABILITIES (A W Hood)		 80
4.1	Equilibrium Solutions	80
4.1.1	Introduction	80
4.1.2	Energetics	80
4.1.3	The Lorentz Force	82
4.1.4	Magnetohydrostatic (MHS) Equilibria	82
4.1.5	Cylindrically Symmetric Magnetic Fields	83
4.1.6	2-Dimensional Magnetic Fields	85
4.2	Physical Description of MHD Instabilities	86
4.3	Linearised MHD Equations	88
4.4	Normal Modes Method	91
4.5	Energy (or Variational) Method	91
4.6	The Rayleigh-Taylor Instability	94
4.6.1	Normal Modes - Two Fluids	94
4.6.2	Normal Modes - Continuous Fluid	96
4.6.3	Simple Energy Method - Two Fluids	96
4.6.4	Energy Method - Continuous Fluid	97
4.6.5	MHD Incompressible Rayleigh-Taylor Instability	97
4.7	The Sharp Pinch - Normal Modes	99
4.7.1	Inner Solution $r < a$	100
4.7.2	Outer Solution $r > a$	101
4.7.3	Matching Conditions at $r = a$	101
4.8	General Cylindrical Pinch - Energy Method	105
4.8.1	Minimisation of $\delta_2 W$	105
4.8.2	Suydam's Criterion - A Necessary Condition	106
4.9	Necessary and Sufficient Conditions - Newcomb's Analysis	109
4.10	Resistive Instabilities - Tearing Modes	111
4.10.1	Introduction	111
4.10.2	The Analysis of FKR	112
4.11	Applications of MHD Instabilities	118
4.11.1	Introduction	118
4.11.2	Ideal Kink Instability of Coronal Loops	118
4.11.3	Two-Ribbon Flares	119
	References	120
 CHAPTER 5 MAGNETIC RECONNECTION (S W H Cowley)		 121
5.1	Introduction	121

5.2 Reconnection: What It Is and What It Does	122
5.3 Fluid (MHD) Models of Reconnection	132
5.4 The Single-Particle Approach in a Collision-Free Plasma	140
References	154
 CHAPTER 6 MAGNETOCONVECTION (N O Weiss)	 156
6.1 Small Flux Tubes	156
6.2 Convection in a Strong Magnetic Field	160
6.3 Structure of the Large-Scale Magnetic Field	169
References	170
 CHAPTER 7 ASPECTS OF DYNAMO THEORY (H K Moffatt)	 172
7.1 The Homopolar Disc Dynamo	172
7.2 The Stretch-Twist-Fold Dynamo	174
7.3 Behaviour of the Dipole Moment in a Confined System	175
7.4 The Pros and Cons of Dynamo Action	176
7.5 Flux Expulsion and Topological Pumping	177
7.6 Mean-Field Electrodynamics	180
7.7 Some Properties of the Pseudo-Tensors α_{ij} and β_{ijk}	182
7.8 The Solar Dynamo	184
7.9 Magnetic Buoyancy as an Equilibration Mechanism	187
References	188
 CHAPTER 8 SOLAR WIND AND THE EARTH'S BOW SHOCK (S J Schwartz)	 190
8.1 The Solar Wind as a Fluid	190
8.1.1 Fluid Models of the Solar Wind	191
8.1.2 Solar Wind Magnetic Fields	193
8.1.3 Mass and Angular Momentum Loss	194
8.1.4 Refinements of Fluid Models	195
8.2 The Solar Wind as a Plasma	197
8.2.1 Why a Plasma Description is Needed	197
8.2.2 Solar Wind Protons	198
8.2.3 Minor Ions in the Solar Wind	200
8.2.4 Waves in the Solar Wind	200
8.3 The Earth's Bow Shock	203
8.3.1 Why a Shock is Needed	203
8.3.2 General Shock Considerations	204
8.3.3 Macroscopic Fields at Collisionless Shocks	206
8.3.4 Particle Dynamics at Collisionless Shocks - Electrons	209
8.3.5 Particle Dynamics at Collisionless Shocks - Ions	214
8.3.6 The Global Structure of the Earth's Bow Shock and Foreshock	220
8.4 Conclusion	221
References	222

CONTENTS

CHAPTER 9	PLANETARY MAGNETOSPHERES (F Bagenal)	224
9.1	Comparative Theory of Magnetospheres	224
9.1.1	Obstacles in a Flowing Plasma	225
9.1.2	Plasma Sources	228
9.1.3	Magnetospheric Flows	229
9.2	Planetary Magnetospheres	232
9.2.1	Mercury	233
9.2.2	Venus	234
9.2.3	Earth	236
9.2.4	Mars	238
9.2.5	Jupiter	239
9.2.6	Saturn	247
9.2.7	Uranus	250
9.2.8	Neptune and Pluto	253
9.3	Conclusions	253
	References	254
CHAPTER 10	COMETS (A D Johnstone)	257
10.1	Introduction to Comet Structure	257
10.2	Interaction between the Solar Wind and the Comet	259
10.3	Production of Neutral Gas	262
10.3.1	Vaporisation	262
10.3.2	Neutral Gas Density	264
10.4	Ionisation	265
10.4.1	Ionisation Processes	265
10.4.2	Size of the Coma	267
10.5	Ion Pick-Up	268
10.5.1	Ion Pick-Up Trajectories	268
10.5.2	Stability of the Distribution	270
10.6	Principal Plasma Regimes	271
10.6.1	Main Regions	271
10.6.2	The Contact Surface	272
10.6.3	Bow Shock	275
10.7	Magnetohydrodynamic Flow at a Comet	276
10.7.1	Numerical Solution of the MHD Equations	276
10.7.2	Validity of the MHD Approach	277
10.8	Special Features of the Morphology	278
10.8.1	Rays, Tail Streamers	278
10.8.2	Disconnection Events	280
10.8.3	Dusty Plasmas	280
10.9	Conclusion	280
	References	282
	INDEX	285

