

Contents

	List of Figures	<i>xi</i>
	List of Tables	<i>xxv</i>
	Author Biography	<i>xxvii</i>
	Preface	<i>xxix</i>
	Acknowledgements	<i>xxx</i>
	Acronyms	<i>xxxiii</i>
	Symbols	<i>xxxv</i>
	Introduction	<i>xxxix</i>
1	Hydromagnetic Oscillations in Homogeneous Plasma	<i>1</i>
2	MHD Oscillations in 1D-Inhomogeneous Model Magnetosphere	<i>10</i>
2.1	A Qualitative Picture of MHD Wave Propagation in a 1D-Inhomogeneous Plasma	<i>12</i>
2.2	Model of a Smooth Transition Layer and Basic Equations for MHD Oscillations	<i>15</i>
2.3	FMS Wave Reflected from the Transition Layer in a Cold Plasma. Alfvén Resonance	<i>16</i>
2.4	Alfvén Resonance Excited by a Wave Impulse	<i>20</i>
2.5	Energy Balance in the Problem of an Incident FMS Wave Reflected from the Transition Layer Containing an Alfvén Resonance Point	<i>25</i>
2.6	FMS Wave Reflected from the Transition Layer in a ‘warm’ Plasma. Alfvén and Magnetosonic Resonances	<i>30</i>
2.7	Alfvén Resonance in Non-ideal Plasma. Kinetic Alfvén Waves	<i>37</i>
2.8	FMS Waveguide	<i>43</i>
2.9	Waveguide for Quasilonitudinal Alfvén Waves	<i>47</i>
2.10	Waveguides for Kinetic Alfvén Waves in a ‘cold’ Plasma. Waveguide Mode Attenuation	<i>49</i>
2.11	Waveguide for Kinetic Alfvén and FMS Waves in a ‘warm’ Plasma. Waveguide Mode Resonance	<i>51</i>
2.12	Waveguides in Plasma Filaments	<i>54</i>
2.12.1	Axisymmetric Plasma Waveguide for Quasi-Longitudinal Alfvén Waves	<i>56</i>
2.12.2	Axisymmetric Plasma Waveguide for Kinetic Alfvén and FMS Waves	<i>58</i>
2.12.3	Waveguide Propagation of Geomagnetic Pulsations in the Outer Magnetosphere	<i>60</i>

2.13	FMS Wave Passing Through a Tangential Discontinuity	62
2.13.1	Model Medium and Matching MHD Equation Solutions	63
2.13.2	Energy Flux Transferred by FMS Waves Through the Magnetopause	67
2.14	Unstable MHD Shear Flows in the Presence/Absence of Boundary Walls	70
2.14.1	Model of Medium and Basic Equations	71
2.14.2	Types of Boundary Conditions	73
2.14.3	Unstable Shear Flows in a Boundless Medium	74
2.14.3.1	The $k_t \parallel B_0$ Case	75
2.14.3.2	The $k_t \perp B_0$ Case	77
2.14.4	Instability of the Shear Flow Bounded by One Rigid Wall	77
2.14.4.1	The $k_t \parallel B_0$ Case	77
2.14.4.2	The $k_t \perp B_0$ Case	79
2.14.5	Shear Flow Instability Between Two Boundary Walls	81
2.14.5.1	The $k_t \parallel B_0$ Case	81
2.14.5.2	The $k_t \perp B_0$ Case	82
2.15	Geotail Instability Due to Shear Flow at the Magnetopause	83
2.15.1	Model Medium and Basic Equations	84
2.15.2	Calculating the Magnetopause MHD Instability Growth Rate in the Tangential Discontinuity Model	88
2.15.3	Geotail Instability in a Smooth-Boundary Model	94
2.15.4	K-H Instability of Global Modes in the Geotail	95
2.16	Kelvin–Helmholtz Instability in the Geotail Low-Latitude Boundary Layer	98
2.16.1	Cylindrical Model of the Geotail Near LLBL	99
2.16.2	Basic Equation and Boundary Conditions for MHD Oscillations in the Cylindrical Coordinate System	103
2.16.3	Numerical Solution of the Basic Equation and Discussion	105
2.17	Cherenkov Radiation of the Fast Magnetoacoustic Waves	111
2.17.1	The Single Fourier-Harmonic	112
2.17.2	Summation of the Fourier-Harmonics	113
2.18	MHD Oscillation Field Penetrating from the Magnetosphere to Ground	115
2.18.1	Boundary Conditions for MHD Waves at the Upper Ionospheric Boundary in a ‘Thin Layer’ Model with a Vertical Magnetic Field	117
2.18.2	Alfvén Waves Penetrating to Ground from the Magnetosphere in a Model Geospace with an Inclined Magnetic Field	120
2.18.2.1	Low-Frequency Electromagnetic Oscillation Field in the Ground and Atmosphere	122
2.18.2.2	Low-Frequency Electromagnetic Oscillation Field in the Ionosphere	122
2.18.2.3	Boundary Conditions for Alfvén Waves at the Upper Boundary of the Ionosphere	128
2.18.2.4	Electromagnetic Oscillations Induced on the Earth Surface by Magnetospheric Alfvén Waves	130
3	MHD Oscillations in 2D-Inhomogeneous Models	133
3.1	Resonance Between FMS and Kinetic Alfvén Waves in a Dipole-Like Magnetosphere	137
3.1.1	Longitudinal Structure of Toroidal Alfvén Waves	141

3.1.2	Structure of Resonant Kinetic Alfvén Waves Across Magnetic Shells	143
3.1.3	Feedback from Resonant Alfvén Oscillations to FMS Wave Field	146
3.2	Alfvén Resonance in a Dipole-Like Magnetosphere	146
3.2.1	Model of the Medium and Basic Equations	147
3.2.2	Resonant Alfvén Wave Field Structure	149
3.2.3	Field Structure of Monochromatic FMS Oscillations in a Dipole-Like Magnetosphere	151
3.2.4	MHD Oscillation Magnetic Field Amplitude Distribution in the Meridional Plane	154
3.3	Resonant Alfvén Waves Excited in a Dipole-Like Magnetosphere by Broadband Sources	158
3.3.1	Monochromatic Source of FMS Waves	159
3.3.2	Pulse Source of FMS Waves	160
3.3.3	FMS Wave Source in the Form of a Wave Packet (Substorm Pi2 Model)	161
3.3.4	Stochastic Source of FMS Waves (Dayside Pc3 Model)	162
3.4	Magnetosonic Resonance in a Dipole-Like Magnetosphere	164
3.4.1	Self-Consistent Model of a Dipole Magnetosphere with Rotating Plasma	164
3.4.2	Basic Equations for Magnetosonic Waves	169
3.4.3	Structure of Standing SMS Waves Along Magnetic Field Lines	171
3.4.4	Structure of Resonant SMS Oscillations Across Magnetic Shells	172
3.4.5	The Field Component Structure of Resonant SMS Oscillations Near the Resonance Surface	174
3.4.6	Numerical Solutions of Equations for Resonant SMS Waves	175
3.5	FMS Oscillations in a Dipole-Like Magnetosphere	178
3.5.1	Longitudinal Structure of FMS Oscillations	178
3.5.2	FMS Oscillation Structure Across Magnetic Shells	184
3.6	FMS Resonators in Earth's Magnetosphere	185
3.6.1	Qualitative Proof that FMS Resonators Exist in the Magnetosphere	185
3.6.2	FMS Resonators in the Dayside Magnetosphere	190
3.6.3	FMS Resonator in the Near-Earth Plasma Sheet	193
3.6.3.1	Model of the Medium	194
3.6.3.2	Coordinate System and Basic Equations	195
3.7	Monochromatic Transverse-Small-Scale Alfvén Waves with $m \gg 1$ in a Dipole-Like Magnetosphere	200
3.7.1	Formulating the Problem of the Alfvén Oscillation Structure in the WKB Approximation	201
3.7.2	Qualitative Investigation of the Eigenvalue Problem	203
3.7.3	Structure of High- m Alfvén Waves Along Magnetic Field Lines	208
3.7.4	Dissipation of Standing Alfvén Waves in the Ionosphere	213
3.7.5	Amplitude Distribution of High- m Alfvén Oscillations Across Magnetic Shells	215
3.7.6	Solution Near the Poloidal Resonance Surface	218
3.7.7	Solution Near the Toroidal Resonance Surface	220
3.7.8	Global Structure of High- m Alfvén Wave (Matching the Solutions for Different Regions)	222

- 3.8 Electromagnetic Oscillations Induced at Earth Surface by Magnetospheric Standing High- m Alfvén Waves 226
- 3.9 Linear Transformation of Standing High- m Alfvén Waves Near the Toroidal Resonance Surface 232
- 3.10 Magnetospheric Resonator for Standing High- m Alfvén Waves 238
- 3.11 High- m Alfvén Waves Generated in the Magnetosphere by Stochastic Sources 241
 - 3.11.1 Expressions for Physical Components of Alfvén Oscillation Magnetic Field 241
 - 3.11.2 Statistical Properties of the Oscillation Source 244
 - 3.11.3 Spectral and Polarisation Properties of Alfvén Noise 246
- 3.12 Broadband Standing High- m Alfvén Waves Generated by Correlated Sources 251
 - 3.12.1 Response of Magnetospheric Alfvén Oscillations to Instantaneous Pulse 253
 - 3.12.2 Conclusions vs. Observations 258
- 3.13 Model Equation to Determine the Transverse Structure of Standing Alfvén Waves in the Magnetosphere 260
 - 3.13.1 Deriving the Homogeneous Model Equation (in the Absence of an Oscillation Source) 261
 - 3.13.2 Inhomogeneous Model Equation 264
 - 3.13.3 Analytical Solution of the Model Equation 267
 - 3.13.4 Numerical Investigation of the Model Equation Solutions 272
- 3.14 Spatial Structure of Alfvén Oscillations Excited in the Magnetosphere by Localised Monochromatic Source 275
 - 3.14.1 Structure of Monochromatic Alfvén Oscillations from a Source Localised Across Magnetic Field Lines 275
 - 3.14.2 Transverse Structure of Standing Alfvén Waves from a Source Strongly Localised in One of the Transverse Coordinates 276
 - 3.14.3 Transverse Structure of Standing Alfvén Waves from a Source Localised in Two Transverse Coordinates 278
 - 3.14.4 On the Methods of Measuring the Polarisation Splitting of the Alfvén Oscillations 280
- 3.15 High- m Alfvén Oscillations Generated in the Magnetosphere by Localised Pulse Sources 282
 - 3.15.1 From Monochromatic to Broadband Oscillations 283
 - 3.15.2 Initial Oscillation Regime ($\tau_N \ll 1$) 285
 - 3.15.3 Asymptotic Regime of Oscillations ($\tau_N \gg 1$) 286
 - 3.15.4 Model Plasmasphere and Equations for the Field Components of Standing Alfvén Waves 292
 - 3.15.5 Calculating Alfvén Oscillation Field in the MASSA Experiment 294
- 3.16 Ballooning Instability of Alfvén and SMS Oscillations on Field Lines Crossing the Current Sheet 298
 - 3.16.1 Equation for Ballooning Modes 299
 - 3.16.2 Model of the Medium 302
 - 3.16.3 The Ballooning Instability of MHD Oscillations as Studied in the Local Approximation 306

3.16.4	Calculating the Structure and Spectrum of Standing Alfvén and SMS Waves on Elongated Field Lines, in the WKB Approximation	309
3.17	Coupled Alfvén and SMS Oscillation Modes in the Geotail	315
3.17.1	Coupled Mode Structure Along Magnetic Field Lines	315
3.17.2	Linear Transformation of Alfvén and SMS Waves in the Current Sheet	320
3.17.3	Coupled MHD Mode Structure Across Magnetic Shells	324
4	MHD Oscillations in 3D-Inhomogeneous Models of the Magnetosphere	329
4.1	MHD Oscillation Properties in Non-homogeneous Models of the Magnetosphere of Different Dimension	329
4.2	Coordinate System	330
4.3	Basic Equations	331
4.4	Qualitative Investigation of the Equation for Characteristics	334
4.5	Wave Singularity in the 3D-Inhomogeneous Magnetosphere	337
5	Conclusion	341
	Appendixes	349
A	Transverse Dispersion of MHD Waves in a ‘Cold’ and ‘Hot’ Plasma	349
B	Deriving an Equation for MHD Oscillations in a 1D-Inhomogeneous Moving Plasma	349
C	A Model of the Spectral Function of the Solar Wind FMS Oscillations	351
D	Stability of MHD Oscillations with $k_t \parallel B_0$, in the Shear Layer, for $\beta^* < 1$ in a Boundless Medium	353
E	Deriving Equations for Potentials φ and ψ for MHD Waves in a ‘Warm’ Plasma, in a Curvilinear Orthogonal System of Coordinates (x^1, x^2, x^3)	353
F	WKB Solution of the Longitudinal Problem for FMS Waves Having Two Turning Points on the Field Line	355
G	Integrals of Functions $G(z)$ and $g(z)$ Describing the Transverse Structure of Standing Alfvén Waves	357
H	Parameters of the Polarisation Ellipse of Stochastic Oscillations	357
I	Deriving Coefficients of the Differential Equation Based on the Given WKB Solution	358
J	Strictly Deriving a Transverse Model Equation for Standing Alfvén Waves, for the $\kappa \ll 1$ Case	359
K	Calculating Characteristics η_0	362
L	Calculating the Integral (3.390) Near the Characteristics $\pm\eta_1, \pm\eta_4$ and η_0	362
M	Calculating the Integral (3.388) Near the Characteristics $\pm\eta_2, \pm\eta_3, \pm\eta_5$ and $\pm\eta_6$	363
N	Determining the Shape of a Field Line from Given Components of Background Magnetic Field	364
O	Defining Tri-orthogonal System of Coordinates Related to Magnetic-Field Lines	365
P	Determining Metric Tensor Components in a Curvilinear Orthogonal System of Coordinates	366

Q	Coefficients of the Equation for the Coupled Modes of MHD Oscillations	367
R	Equation for MHD Oscillations in a Cylindrical Coordinate System	368
S	Equality of the Alfvén Oscillation Specific Power Absorbed Near the Resonance Surface and the Density of Energy Carried Away by KAWs	369

References 372

Index 401