# CONTENTS


## MAGNETOTHERMAL PROCESSES IN DENSE PLASMAS

**G. E. Vekshtein**

Introduction ..... 1
1. Cooling and Anomalous Heat Conduction in Plasmas with $\beta \gg 1$ ..... 3
2. Radiative Cooling Waves in Dense Magnetized Plasmas ..... 20
3. Loss of Magnetic Flux during Field Reversal in $\theta$-Pinches ..... 27
4. Generation of Very Strong Magnetic Fields by Liner Compression of Plasmas ..... 34
5. Rapid Dissipation of Magnetic Field Energy in Neutral Layers ..... 38
6. Diffusion of Heavy Impurities in Dense Plasmas ..... 43
7. Radiative Instability in Multicomponent Plasmas ..... 49

Appendix ..... 55
References ..... 57

## COLLECTIVE INTERACTION OF RELATIVISTIC ELECTRON BEAMS WITH PLASMAS

**B. N. Breizman**

Introduction ..... 61

1. Linear Dispersion Equation. Resonances in the Excitation of Waves by Particles ..... 62
2. Beam Instability in a Plasma without a Magnetic Field [the Excitation of Langmuir Waves] ..... 66
3. Hydrodynamic Instabilities of Beams in Magnetoactive Plasmas ..... 72
3.1. Excitation of Langmuir Waves ..... 74
3.2. Excitation of Helicons ..... 75
3.3. Excitation of Magnetized Electron Oscillations with $|\omega_H| >> \omega_p$ ..... 76
3.4. Excitation of Slow Extraordinary Waves ..... 78
4. Kinetic Instabilities of Beams in Magnetoactive Plasmas ..... 80
4.1. Excitation of Langmuir Waves with $\omega_H << \omega_p$ ..... 80
4.2. Excitation of Helicons ..... 82
4.3. Excitation of Magnetized Electron Oscillations ..... 83
4.4. Excitation of Slow Extraordinary Waves ..... 84
5. Beam Instability in an Inhomogeneous Plasma ..... 85
5.1. Regular Inhomogeneity ..... 85
5.2. Random Inhomogeneity ..... 87
6. Quasilinear Relaxation of an REB in a Plasma without a Magnetic Field ..... 92
7. Nonlinear Interaction and Streaming Spectra of Langmuir Waves ..... 98
8. Stability of the Stationary Spectrum during Stimulated Wave Scattering ..... 105
9. Relaxation of an REB during Wave Scattering on Ions ..... 108
9.1. Qualitative Treatment ..... 108
9.2. The Stationary Spectrum ..... 112
9.3. Diffusion of Beam Electrons ..... 116
9.4. Collisional Damping and Radiative Losses ..... 118
10. Accumulation of Electromagnetic Waves ..... 121
11. Scattering of Langmuir Waves on Stimulated Density Fluctuations ..... 127
12. Langmuir Turbulence in Magnetoactive Plasmas ..... 133
12.1. Statement of the Stream Spectrum Problem ..... 133
12.2. The *ll*-Scattering Regime ..... 136
12.3. *lt*-Scattering ..... 139
13. Interaction of Beams with Helicons ..... 141
13.1. Qualitative Treatment ..... 141
13.2. Solution of the Quasilinear Problem ..... 143
13.3. Discussion of Results ..... 149
14. Hot Electrons ..... 151
14.1. Electron Heating in Plasmas without a Magnetic Field ..... 151
14.2. Electron Heating in Magnetoactive Plasmas ..... 154
References ..... 159



## EQUILIBRIUM AND STABILITY OF PLASMAS IN STELLARATORS

**V. D. Pustovitov and V. D. Shafranov**

Introduction ..... 163
1. Basic Results of the Theory ..... 167
1.1. Development of Theoretical Research ..... 167
1.2. Basic Parameters of Stellarators ..... 176
1.3. Plasma Confinement in Stellarators with a Spatial Axis ..... 179
1.4. Plasma Confinement in Conventional Stellarators ..... 185
1.5. Results of a Numerical Calculation ..... 192
2. The Three-dimensional Equilibrium Equations ..... 203
2.1. The Magnetic Field in Flux Coordinates ..... 203
2.2. Special Choices of Flux Coordinates ..... 209
2.3. The Relationship between Currents and Fluxes ..... 216
2.4. General Statement of the Equilibrium Problems ..... 220
2.5. The Equilibrium Problem in Terms of Two-Dimensional Equations. Evolution of the Equilibrium ..... 222
2.6. Systems of Three-Dimensional Equilibrium Equations in Different Representations ..... 225
3. Configurations with Helical Symmetry ..... 229
3.1. The Equilibrium Equations ..... 229
3.2. Basic Geometrical Relationships ..... 233
3.3. Equations Relating the Currents and Fluxes ..... 239
3.4. Other Formulations of the Equilibrium Equations ..... 242
4. The Theory of Plasma Equilibrium in Conventional Stellarators ..... 245
4.1. The Stellarator Approximation ..... 245
4.2. Flux Coordinates, Basic Equations, and Features of Their Solution by Expansion ..... 247
4.3 Reducing the Three-Dimensional Equilibrium Equations to Two Dimensions ..... 252
4.4. Analysis of the Two-Dimensional Equations. Other Formulations of Them ..... 255
4.5. Derivation of the Scalar Two-Dimensional Equilibrium Equation from the Averaged MHD Equations ..... 260
4.6. Intrinsic Expansion Parameters ..... 262
5. Some Features of Plasma Equilibrium in Stellarators ..... 265
5.1. Approximate Description of Equilibrium ..... 265
5.2. Evolution of the Plasma Equilibrium in Stellarators ..... 276
5.3. The Diamagnetic Effect in Stellarators ..... 284
6. MHD Instabilities of Plasmas ..... 291
6.1. Perturbation Equations ..... 291

6.2. The Energy Principle ..... 295
6.3. Integral Quantities ..... 297
6.4. Different Representations of the Instability Source $K$ ..... 299
6.5. Sufficient Criteria for Stability ..... 301
6.6. Derivation of the Mercier Criterion ..... 305
6.7. Derivation of the Ballooning Mode Equations ..... 308
Appendices ..... 311
References ..... 319