

Contents

<i>Preface</i>	<i>page xi</i>
I General Introduction	1
1.1 Brief History	2
1.2 Chaos and Unpredictability	12
1.3 Transition to Turbulence	14
1.4 Statistical Tools and Symmetries	17
<i>References</i>	20
Part I Fundamentals of Turbulence	25
2 Eddy Turbulence in Hydrodynamics	27
2.1 Navier–Stokes Equations	27
2.2 Turbulence and Heating	27
2.3 Kármán–Howarth Equation	33
2.4 Locality and Cascade	35
2.5 Kolmogorov’s Exact Law	37
2.6 Phenomenology of Eddy Turbulence	39
2.7 Inertial Dissipation and Singularities	40
2.8 Intermittency	46
2.9 Compressible Turbulence	57
<i>References</i>	65
3 Spectral Theory in Hydrodynamics	69
3.1 Kinematics	69
3.2 Detailed Energy Conservation	71
3.3 Statistical Theory	74

3.4 Two-Dimensional Eddy Turbulence	82
3.5 Dual Cascade	93
3.6 Nonlinear Diffusion Model	93
<i>References</i>	96
Exercises I	99
I.1 1D HD Turbulence: Burgers' Equation	99
I.2 Structure Function and Spectrum	99
I.3 2D HD Turbulence: Detailed Conservation	100
<i>References</i>	100
Part II Wave Turbulence	101
4 Introduction	103
4.1 Brief History	104
4.2 Multiple Scale Method	111
4.3 Weakly Nonlinear Model	115
<i>References</i>	122
5 Theory for Capillary Wave Turbulence	127
5.1 Introduction	127
5.2 Phenomenology	130
5.3 Analytical Theory: Fundamental Equation	132
5.4 Analytical Theory: Statistical Approach	136
5.5 Detailed Energy Conservation	140
5.6 Exact Solutions and Zakharov's Transformation	141
5.7 Nature of the Exact Solutions	145
5.8 Comparison with Experiments	147
5.9 Direct Numerical Simulation	149
<i>References</i>	152
6 Inertial Wave Turbulence	155
6.1 Introduction	155
6.2 What Do We Know About Rotating Turbulence?	157
6.3 Helical Inertial Waves	161
6.4 Phenomenological Predictions	162
6.5 Inertial Wave Turbulence Theory	164
6.6 Local Triadic Interactions	167

Contents**ix**

6.7 Perspectives	174
<i>References</i>	175
7 Alfvén Wave Turbulence	179
7.1 Incompressible MHD	180
7.2 Strong Alfvén Wave Turbulence	181
7.3 Phenomenology of Wave Turbulence	185
7.4 Theory of Alfvén Wave Turbulence	189
7.5 Direct Numerical Simulation	196
7.6 Application: The Solar Corona	197
7.7 Perspectives	200
<i>References</i>	201
8 Wave Turbulence in a Compressible Plasma	205
8.1 Multiscale Solar Wind	206
8.2 Exact Law in Compressible Hall MHD	209
8.3 Weakly Compressible Electron MHD	212
8.4 Kinetic Alfvén Waves (KAW)	216
8.5 Spectral Phenomenology	216
8.6 Theory of Weak KAW Turbulence	219
8.7 Inertial/Kinetic-Alfvén Wave Turbulence: A Twin Problem	223
8.8 Perspectives	226
<i>References</i>	227
9 Gravitational Wave Turbulence	231
9.1 Primordial Universe	231
9.2 Weak Gravitational Wave Turbulence	234
9.3 Strong Turbulence and Inflation	241
9.4 Perspectives	242
<i>References</i>	242
Exercises II	245
II.1 MHD Model of Nonlinear Diffusion	245
II.2 Four-Wave Interactions	246
II.3 Gravitational Wave Turbulence: Exact Solutions	246
II.4 Inertial Wave Turbulence: Domain of Locality	247
<i>References</i>	247
<i>Appendix A Solutions to the Exercises</i>	249

I.1 1D HD Turbulence: Burgers' Equation	249
I.2 Structure Function and Spectrum	253
I.3 2D HD Turbulence: Detailed Conservation	255
II.1 MHD Model of Nonlinear Diffusion	259
II.2 Four-Wave Interactions	261
II.3 Gravitational Wave Turbulence: Exact Solutions	262
II.4 Inertial Wave Turbulence: Domain of Locality	265
<i>References</i>	269
<i>Appendix B Formulary</i>	271
<i>Index</i>	275