

Contents

1. Introduction. By H. L. Swinney and J. P. Gollub	1
1.1 Experimental Difficulties and Advances	1
1.2 Hydrodynamic Stability and Bifurcation	3
1.3 Dynamical Systems	3
1.4 Convection, Rotation, and Shear Flows	4
1.5 Instabilities in Geophysics and Nonhydrodynamic Systems	5
1.6 Summary	5
References	6
2. Strange Attractors and Turbulence. By O. E. Lanford (With 1 Figure)	7
2.1 Basic Principles	7
2.2 Some Elements of the Qualitative Theory of Differential Equations	10
2.3 Statistical Theory	19
References	25
3. Hydrodynamic Stability and Bifurcation	
By D.D. Joseph (With 14 Figures)	27
3.1 The Navier-Stokes Equations and the Prescribed Data	27
3.2 Uniqueness and Stability of Solutions when the Reynolds	
Number is Small	30
3.3 Instability and Transition into Turbulence	32
3.4 Examples of Hydrodynamic Stability and Bifurcation	37
3.5 A Simplified Mathematical Discussion of some General Proper-	
ties of Stability and Bifurcation	42
3.6 Isolated Solutions Which Perturb Bifurcation	52
3.7 Bifurcation of Steady Flow into Time-Periodic Flow	56
3.8 Finite Dimensional Projections.	61
3.9 Bifurcation, Stability, and Transition in Poiseuille and Couette	
Flows	67
3.10 Bibliographical Notes and Comments on Methods of Analysis .	70
References	73
4. Chaotic Behavior and Fluid Dynamics	
By J. A. Yorke and E. D. Yorke (With 4 Figures)	77
4.1 Background	77
4.2 The Lorenz Equations	78

4.3 Landau's Idea: A Continuous Transition to Turbulence via an Infinite Cascade of Bifurcations	84
4.4 One-Dimensional Maps: A Continuous Transition to Chaos via an Infinite Cascade of Bifurcations	87
4.5 Long-Term Average Behavior	90
4.6 Metastable Chaotic States	92
References	94
5. Transition to Turbulence in Rayleigh-Bénard Convection	
By F.H. Busse (With 13 Figures)	97
5.1 Overview	97
5.2 Linear Theory	100
5.2.1 Basic Equations	100
5.2.2 The Onset of Convection	102
5.3 Nonlinear Theory	106
5.3.1 The Perturbation Approach	106
5.3.2 Numerical Computations	109
5.3.3 The Optimum Theory of Turbulent Convection	113
5.4 Experimental Observations	116
5.4.1 Steady Convection	116
5.4.2 Transitions	118
5.4.3 Turbulent Convection	121
5.5 Instabilities of Convection Rolls	124
5.5.1 Theoretical Analysis	124
5.5.2 Wavelength Changing Instabilities	125
5.5.3 Pattern Changing Instabilities	126
5.6 Convection in a Rotating Layer	129
5.7 Concluding Remarks	132
References	133
6. Instabilities and Transition in Flow Between Concentric Rotating Cylinders. By R. C. DiPrima and H. L. Swinney (With 9 Figures)	139
6.1 Background	141
6.2 Instability of Couette Flow	145
6.3 Growth of Taylor Vortices	152
6.4 Wavy Vortex Flow	157
6.5 Higher Instabilities and Turbulence	161
6.5.1 Flow Visualization Experiments	163
6.5.2 Studies of the Flow Spectrum	165
6.5.3 Summary of the Experiments	169
6.5.4 Model Systems	170
6.6 Finite Annulus Length Effects	172
References	176

7. Shear Flow Instabilities and Transition

By S.A.Maslowe (With 10 Figures)	181
7.1 Overview	181
7.2 Linear Stability via the Normal-Mode Approach	184
7.2.1 The Orr-Sommerfeld Equation.	185
7.2.2 The Rayleigh Equation	186
7.2.3 The Reynolds Stress	189
7.2.4 Broken-Line Profiles	192
7.2.5 Asymptotic Solution of the Orr-Sommerfeld Equation	194
7.2.6 Numerical Solution of the Rayleigh and Orr-Sommerfeld Equations.	198
7.3 The Linear Initial-Value Problem	200
7.3.1 Inviscid Theory	201
7.3.2 The Initial-Value Problem at Finite Reynolds Number	203
7.3.3 Wave Packets	203
7.4 Nonlinear Theories	205
7.4.1 Weakly Nonlinear Theory.	205
7.4.2 The Nonlinear Critical Layer	210
7.4.3 Time Dependence and the Nonlinear Critical Layer.	215
7.5 Transition Experiments and some Theoretical Offspring	216
7.5.1 Free Shear Layer Transition.	216
7.5.2 Boundary Layer Transition	219
7.5.3 Poiseuille Flow	222
7.6 Concluding Remarks	223
References	225

8. Instabilities in Geophysical Fluid Dynamics

By D.J. Tritton and P.A. Davies (With 23 Figures)	229
8.1 Overview	230
8.2 Consequences of Instabilities in Nature	231
8.3 Stratified Shear Flow	234
8.3.1 The Richardson Number	235
8.3.2 Stably Stratified Free Shear Layers.	237
8.3.3 Wall Flows	240
8.3.4 Horizontal Shear	241
8.4 Shear Flows in Rotating Fluids	242
8.4.1 Stabilizing and Destabilizing Effects of Rotation	242
8.4.2 Theoretical and Experimental Examples.	245
8.4.3 The β Effect	248
8.5 Baroclinic Instability in a Rotating Fluid.	249
8.5.1 The Eady Problem.	250
8.5.2 Symmetric Baroclinic Instability	252
8.5.3 Annulus Experiments.	252
8.5.4 Two-Layer Flows	257

8.6 Multidiffusive Instabilities	258
8.6.1 Linear Stability Theory	259
8.6.2 Diffusive Layering	260
8.6.3 Salt Fingers	262
8.6.4 Sideways Diffusive Instability	262
8.6.5 Nonthermohaline Double Diffusion	264
References	265
9. Instabilities and Chaos in Nonhydrodynamic Systems	
By J. M. Guckenheimer (With 7 Figures)	271
9.1 The Rikitake Dynamo Model for the Earth's Magnetic Field	271
9.2 The Belousov-Zhabotinskii Chemical Reaction	274
9.3 A Model for Population Dynamics	276
9.4 The van der Pol Equation	277
9.5 A Dynamical Systems Analysis of the van der Pol Model	280
9.6 Discussion	285
References	286
10. Recent Progress. By F. H. Busse, J. P. Gollub, S. A. Maslowe, and H. L. Swinney (With 1 Figure)	289
10.1 Introductory Comments	289
10.2 Rayleigh-Bénard Convection	289
10.2.1 Routes to Chaos in Convection	289
10.2.2 Pattern Evolution and Defects in Large Aspect Ratio Convection Layers	290
10.2.3 Other Time-Dependent Phenomena	291
10.2.4 Convection with Magnetic Field	291
10.3 Instabilities and Transition in Flow Between Concentric Cylinders	292
10.3.1 Taylor Vortex Flow and Finite Length Effects	293
10.3.2 Wavy Vortex Flow and Other Periodic and Multi-Periodic Flows	294
10.3.3 Chaos and Turbulence	294
10.3.4 Theory and Numerical Analysis	295
10.4 Shear Flow Instabilities and Transition	295
10.5 Instabilities and Chaos in Other Systems	297
10.6 Conclusion	297
References	297
Subject Index	303