

Contents

<i>Preface</i>	vii
1. Dynamics of Coupled and Driven Harmonic Oscillators	1
1.1 The harmonic oscillator	1
1.1.1 The free harmonic oscillator	2
1.1.2 Damped harmonic oscillator	5
1.2 Driven and coupled harmonic oscillators	6
1.2.1 Periodically driven harmonic oscillator: resonance . .	7
1.2.2 Coupled harmonic oscillators: normal modes	10
1.3 Nonlinear oscillators	12
2. Chaotic Oscillators	17
2.1 Nonlinear flows and maps	17
2.2 Poincaré maps and bifurcation diagrams	24
2.3 Lyapunov exponents	32
2.4 Power spectra	40
2.5 Unstable periodic orbits	44
2.6 Time series analysis	49
3. Periodically Driven Chaotic Oscillators	53
3.1 Phase synchronization	53
3.1.1 Phase of a chaotic oscillator	54
3.1.2 Characterization of phase synchronization	61
3.1.3 Numerical simulations and experimental evidence . .	67
3.2 Chaos suppression	71
3.2.1 Weak resonant forces	72

3.2.2	Numerical and experimental observations	76
4.	Chaotic Oscillators Driven by Chaotic Signals	79
4.1	Driving schemes	79
4.2	Identical systems	82
4.2.1	Synchronization and its stability	83
4.2.2	Marginal synchronization of chaos	87
4.2.3	Anticipated synchronization	91
4.2.4	Synchronization in simulations and experiments	94
4.3	Non-Identical systems	98
4.3.1	Generalized synchronization	98
4.3.2	Observation of generalized synchronization	107
5.	Perturbing Chaotic Systems to Control Chaos	111
5.1	The OGY method	111
5.1.1	Stabilization of unstable periodic orbits	111
5.1.2	Experiments and applications	120
5.2	The Pyragas method	123
5.2.1	Delayed feedback control	123
5.2.2	Experimental realizations	127
6.	Mutually Coupled Identical Chaotic Oscillator	133
6.1	Synchronization of two coupled oscillators	133
6.1.1	Synchronized motion and its stability	134
6.1.2	Complexity in the transition to the synchronized state	139
6.1.3	Numerical simulations and experiments	143
6.2	Dynamics of systems of $N > 2$ coupled oscillators	147
6.2.1	Basic theory	147
6.2.2	Partial synchronization of chaos	149
6.2.3	Computer simulations and laboratory experiments	151
7.	Mutually Coupled Non-Identical Oscillators	155
7.1	Degrees of chaotic synchronization	155
7.1.1	Amplitude envelope synchronization	156
7.1.2	Phase synchronization	161
7.1.3	Lag synchronization	167
7.2	Observations of synchronization phenomena	172
7.2.1	Numerical simulations	172

7.2.2	Laboratory experiments	174
7.3	Systems of $N > 2$ non-identical oscillators	176
8.	On the Dynamics of Coupled and Driven Chaotic Oscillators	181
8.1	An overview	181
8.1.1	Oscillators	181
8.1.2	Driven chaotic oscillators	183
8.1.3	Mutually coupled chaotic oscillators	186
8.2	On the scientific and technical applications of synchroniza- tion and control	189
8.2.1	Synchronization in neurobiology	189
8.2.2	Synchronization in the Earth sciences	192
8.2.3	Chaotic communications	194
	<i>Bibliography</i>	197
	<i>Index</i>	209