Contents

	Preface	xi
	Introduction	xv
	Part I: Idealized homogeneous systems – basic ideas and gentle relaxation	**1**
1	The average and fluctuating gravitational fields	3
2	Gentle relaxation: timescales	7
3	The dynamics of random impulsive forces	14
4	General properties of Fokker–Planck evolution	21
5	Fokker–Planck description of gravitating systems	29
6	Dynamics with a memory: non-Markovian evolution	34
7	The Boltzmann equation	39
8	Some properties of the Boltzmann equation	44
9	The virial theorem	49
10	The grand description – Liouville's equation and entropy	54
11	Extracting knowledge: the BBGKY hierarchy	64
12	Extracting knowledge: the Fourier development	69
13	Collective effects – grexons	73
14	Collective scattering	77
	14.1. The scattering probability	77
	14.2. Fluctuations, correlations, form factors and the f sum rule for stellar systems	86
	14.3. The deflection angle, dynamical friction again, and a numerical test	90
15	Linear response and dispersion relations	95
	15.1. Basic result	95
	15.2. Gaseous systems	96
	15.3. Stellar systems	100
16	Damping and decay	105
	16.1. Physical description	105
	16.2. Calculation of Landau damping rate	107
	16.3. Other damping mechanisms	114
17	Star–gas interactions	117

17.1. Gas dynamical processes 117
17.2. Accretion and momentum decrease 119
17.3. Jeans and two-stream instabilities 124
18 Problems and extensions 127
18.1. The point mass approximation 127
18.2. Plummer's model 127
18.3. Solutions of the master equation 128
18.4. Self-similar solutions of the collisionless Boltzmann equation 128
18.5. Wave propagation in an inhomogeneous system 130
18.6. Accretion of gas by stars 130
19 Bibliography 131
Part II: Infinite inhomogeneous systems – galaxy clustering 135
20 How does matter fill the Universe? 137
20.1. General description 137
20.2. Quantifying the distribution 143
20.3. Measurement of the galaxy pair correlation function 147
21 Gravitational instability of the infinite expanding gas 151
22 Gravitational graininess initiates clustering 158
23 Growth of the two-galaxy correlation function 163
24 The energy and early scope of clustering 171
25 Later evolution of cosmic correlation energies 175
25.1. The cosmic energy equation 175
25.2. Stability of $\xi(r) \propto r^{-2}$ 178
26 N-body simulations 181
27 Evolving spatial distributions 185
28 Evolving velocity distributions 195
29 Short review of basic thermodynamics 202
29.1. Concepts 202
29.2. Interrelations 206
29.3. Connections with kinetic theory and statistical mechanics 209
29.4. Fluctuations and phase transitions 213
30 Gravity and thermodynamics 215
30.1. Statistical mechanical approach 215
30.2. Kinetic theory approach 218
30.3. Model approach 220
31 Gravithermodynamic instability 222
31.1. The vanishing of sound speed 222
31.2. Spatial fluctuations 226
31.3. Temporal fluctuations 228
31.4. Gravitational phase transitions 230
32 Thermodynamics and galaxy clustering; $\xi(r) \propto r^{-2}$ 233
33 Efficiency of gravitational clustering 238
34 Non-linear theory of high order correlations 245
34.1. Equation of state 245
34.2. The distribution functions $f(N)$ 249

35 Problems and extensions 255
35.1. Gravitational instability in multiple component systems 255
35.2. Pancakes 255
35.3. Fluctuations and semi-invariants 256
36 Bibliography 259
Part III: Finite spherical systems – clusters of galaxies, galactic nuclei, globular clusters 263
37 Breakaway 265
38 Violent relaxation 270
38.1. Introduction and basic physical ideas 270
38.2. The collisionless distribution function 272
38.3. Criteria for violent relaxation 277
38.4. Damping and computer simulations 280
38.5. Distributions for collisional systems 281
39 Symmetry and Jeans' theorem 287
40 Quasi-equilibrium models 290
40.1. Polytropes and isothermal spheres 290
40.2. Loaded polytropes 294
40.3. Fokker–Planck models 299
41 Applying the virial theorem 303
42 Observed dynamical properties of clusters 312
42.1. Clusters of galaxies 313
42.2. Galactic nuclei 316
42.3. Globular clusters 318
43 Gravithermal instabilities 321
44 Self-similar transport 328
45 Evaporation and escape 335
46 Mass segregation and equipartition 340
47 Orbit segregation 346
48 Binary formation and cluster evolution 352
48.1. Formation by few-body interactions 352
48.2. Formation by stellar dissipation – tidal energy transfer 356
48.3. Effects on cluster evolution 362
49 Slingshot 365
50 Role of a central singularity 369
51 Role of a distributed background 374
52 Physical stellar collisions 378
53 More star–gas interactions 382
53.1. Galactic winds 382
53.2. Central disks and star formation 385
53.3. Embedded stars 387
54 Problems and extensions 388
54.1. Potential energy of a polytrope 388
54.2. Virial mass discrepancy for a system which loses mass 388
54.3. Effect of angular momentum on the contraction of a stellar system 389
54.4. Calculation of slingshot results 389

55	Bibliography	391
	Part IV: Finite flattened systems – galaxies	**397**
56	Observed dynamics of galaxies	399
57	Kinematics of motion	406
	57.1. General kinematics	406
	57.2. Motions in galactic coordinates	410
58	Transfer of angular momentum	414
59	Rotation curves and galaxy mass	420
60	Orbits and third integrals	427
61	Axisymmetric and bar instabilities	438
62	Spiral instabilities	446
	62.1. Introduction	446
	62.2. Basic properties of patterns	447
	62.3. Self-consistent patterns	450
	62.4. Sustaining the spiral	453
63	Triaxial and irregular systems	456
	63.1. Introduction – spinning polytropes	456
	63.2. Computer experiments	461
64	Gravitational shocks	463
65	Passing–merging	466
66	Problems and extensions	471
	66.1. Uniform ellipsoids and Maclaurin spheroids	471
	66.2. Simple evolution of bars	473
	66.3. Distribution function for a uniformly rotating disk of stars	473
	66.4. Models of thick disks	474
	66.5. Origin of the density profiles of elliptical galaxies	474
	66.6. Orbits and adiabatic invariants in a triaxial galaxy	475
67	Unanswered questions	476
68	Bibliography	478
	Index	481