

Contents

<i>Foreword</i>	page xi
<i>Preface</i>	xiii
Part I General Aspects	1
1 Introduction to phase transitions	3
1.1 Thermodynamics: general features	6
1.1.1 Equilibrium and stability	9
1.1.2 Phase coexistence: the Clausius–Clapeyron equation	11
1.2 Extensivity and thermodynamics of small systems	14
1.3 Simple microscopic lattice models. The Ising model	17
1.3.1 The Ising model for non-magnetic systems	19
1.4 Statistical mechanics of lattice models and the mean-field approximation	22
1.4.1 Mean-field approximation	23
1.4.2 Antiferromagnetic case: sublattices	31
1.4.3 Multiple variables: the Deformable Ising model	33
1.5 The Landau approach	37
1.5.1 Ginzburg–Landau approach: spatial fluctuations	43
1.5.2 First-order transitions and tricritical points	46
1.6 Scaling and renormalization	49
Exercises	55
2 Dynamics of phase transitions	62
2.1 Metastable and unstable states in the framework of Landau theory	63

2.2	Dynamic equations: formal treatment	68
2.2.1	Langevin formulation: models A and B	71
2.3	Nucleation	76
2.3.1	Influence of long-range forces: elastic strain	84
2.3.2	Heterogeneous nucleation	84
2.4	Spinodal decomposition	87
2.5	Coarsening and domain growth	91
	Exercises	97

Part II Applications 101

3 Ferroic materials 103

3.1	Phase transitions in ferroic materials	106
3.1.1	Vectorial ferroics	106
3.1.2	Tensor ferroics	110
3.2	Ferromagnetic materials	116
3.2.1	Energy contributions and modelling	117
3.3	Ferroelectric materials	128
3.4	Ferrotoroidic materials	130
3.5	Ferroelastic materials	134
3.5.1	Shape memory materials and shape memory effect	142
	Exercises	145

4 Coupling of ferroic degrees of freedom: multiferroics 151

4.1	Magnetoelectric multiferroics	153
4.1.1	Free energy and magnetoelectric coupling	160
4.2	Electro- and magnetostructural multiferroics	162
4.3	Morphotropic phase boundaries	168
4.3.1	Modeling morphotropic phase boundaries	169
	Exercises	173

5 Caloric and multicaloric materials 175

5.1	Caloric response	177
5.2	Multicaloric effects	187
5.3	Influence of hysteresis	195
	Exercises	198

6 Liquid crystals and topological defects 200

6.1	General features	201
6.2	The orientational order parameter	205
6.3	The Landau–de Gennes model	210

6.3.1	Fluctuation effects, distortion and effect of external fields	213
6.3.2	The nematic to smectic transition	222
6.4	Topological defects	224
	Exercises	237
7	Glassy phenomena in materials with disorder	238
7.1	Magnetic glasses	240
7.1.1	Spin glasses	241
7.1.2	Models for spin glasses	249
7.1.3	Mean-field treatment	251
7.2	Glassy behaviour in polar materials: dipolar glasses and relaxors	260
7.3	Strain glasses	265
	Exercises	270
8	Non-equilibrium phase transitions	272
8.1	Dynamic phase transitions	273
8.2	Disorder-induced transitions	281
8.2.1	Beyond mean-field	288
8.2.2	Avalanches in other systems: breakdown phenomena in systems with disorder	295
	Exercises	298
9	Superconductors	300
9.1	Phenomenology and thermodynamics	302
9.2	The Ginzburg–Landau theory of superconductors	308
9.2.1	The Ginzburg–Landau theory in the presence of an applied magnetic field	312
9.2.2	The analogy between type II superconductors and smectic A liquid crystals	318
9.3	The BCS theory: a microscopic explanation	320
	Exercises	330
10	Quantum phase transitions	332
10.1	Thermal and quantum phase transitions	333
10.1.1	Examples	337
10.2	Quantum Ising systems	343
10.2.1	Quantum-classical mapping	346
	Exercises	351
	Appendix: Landau theory and symmetry	353
A.1	Introduction: symmetry considerations	353

A.2	Ferroelastic transitions	355
A.3	Phonon-driven and ferroelectric transitions	360
A.4	Colour symmetry and magnetic transitions	363
A.5	Common subgroup method for reconstructive transitions	366
<i>References</i>		370
<i>Materials Index</i>		389
<i>General Index</i>		391