

Contents

Prologue

v

Chapter 1. History of Magnetism	1
1.1. Physics and Metaphysics	3
1.2. Gilbert and Descartes	6
1.3. Rise of Modern Science	12
1.4. Electrodynamics	16
1.5. The Electron	23
1.6. The Demise of Classical Physics	26
1.7. Quantum Theory	31
1.8. Modern Foundations	35
1.9. Magnetic Bubbles	39
1.10. Ultimate Thin Films	44
1.11. Dilute Magnetic Alloys	47
1.12. New Directions	49
Chapter 2. Currents or Spins?	53
2.1. Charge Currents or Spins?	53
2.2. The Magnetic Dipole	56
2.3. The Magnetic Dipole-Dipole Interactions	57
2.4. The Exchange Interactions	63
2.5. Metals and Their Alloys	65
2.6. Superconductivity	68
2.7. The Need to Study Spin Angular Momentum	69

Chapter 3. Quantum Theory of Angular Momentum	70
3.1. Kinetic Angular Momentum	70
3.2. Spherical Harmonics	74
3.3. Reason for Integer l and m	78
3.4. Matrices of Angular Momentum	80
3.5. Pauli Spin Matrices	82
3.6. Compounding Angular Momentum	83
3.7. Equations of Motion of Interacting Angular Momenta	87
3.8. Coupled Boson Representation	87
3.9. Rotations	90
3.10. More on Compound Angular Momentum	92
3.11. Other Representations	95
3.12. Spins One-Half: Special Tricks	96
3.13. Spins One	98
3.14. Quadratic Forms	100
3.15. Projection Operators	101
Chapter 4. Magnetism and the Many-Body Problem	104
4.1. Hamiltonian Physics and Degeneracy	104
4.2. The Pauli Principle	107
4.3. The Two-Fermion Problem	111
4.4. Electrons in One Dimension: A Theorem	113
4.5. The Wronskian	116
4.6. States of Three Electrons	118
4.7. Eigenfunctions of Total S^2 and S_z	120
4.8. Hund's Rules	125
4.9. p^3 Configuration	127
4.10. p^2 and p^4 Configurations	133
4.11. Second Quantization	139
4.12. Double Exchange	143
4.13. Superexchange	146
4.14. Jellium	149
4.15. Hubbard Model: An Introduction	154
4.16. Nagaoka's Ferromagnetism	163
4.17. One Dimension: Exact Solutions	167
4.18. Ferrimagnetism	168
4.19. Spin-Dependent Tunneling	172

Chapter 5. From Magnons to Solitons: Spin Dynamics	175
5.1. Spin Waves as Harmonic Oscillators	176
5.2. One-Magnon Eigenstates in Ferromagnets	185
5.3. Two-Magnon States and Eigenstates in Ferromagnets	186
5.4. Bound States in One Dimension	195
5.5. Bound States in Two and Three Dimensions	196
5.6. Antiferromagnetic Magnons: The One-Dimensional XY Model .	200
5.7. Bethe's Solution of One-Dimensional Heisenberg Antiferromagnet	206
5.8. Linearized Antiferromagnetic Magnons	215
5.9. Ferrimagnetism	224
5.10. Some Rigorous Notions in Antiferro- and Ferri-Magnetism . .	226
5.11. Vortices	228
5.12. Solitons and Bloch Domain Walls: Introductory Material . .	231
5.13. Solitary Wave Solution	235
5.14. More on Magnetic Domains	241
5.15. Time-Dependent Phenomena	242
5.16. Majumdar-Ghosh Model and "Quantum Frustration"	247
5.17. Integer Spins	250
5.18. The AKLT Spin One Chain	254
5.19. Defective Antiferromagnets	255
Chapter 6. Magnetism in Metals	257
6.1. Bloch and Wannier States	259
6.2. Tight-Binding	260
6.3. Weak Magnetic Properties	267
6.4. Exchange in Solids: Construction of a Model Hamiltonian . .	273
6.5. Perturbation-Theoretic Derivation of Heisenberg Hamiltonian	281
6.6. Heisenberg Hamiltonian in Metals	284
6.7. Ordered Magnetic Metals: Deriving the Ground State	287
6.8. Kondo Effect	296
6.9. Spin Glasses	304
6.10. Magnetism without Localized Spins: Preliminaries	310
6.11. Degenerate Bands and Intra-Atomic Exchange Forces . . .	314
6.12. Magnons in Metals	320
6.13. Marginal Magnetism of Impurities	327
6.14. Correlations and Equivalence to $s-d$ Model	337
6.15. Periodic Anderson Model	342

Chapter 7. Statistical Thermodynamics	344
7.1. Spins in a Magnetic Field	344
7.2. The Partition Function	349
7.3. The Concept of the Molecular Field	354
7.4. Discontinuity in Specific Heat	358
7.5. Magnetic Susceptibility and Spontaneous Magnetization	361
7.6. Adiabatic Demagnetization	365
7.7. Antiferromagnetism	366
7.8. Short-Ranged versus Long-Ranged Interactions	369
7.9. Fermions, Bosons, and all that	375
Fermions	375
Bosons	375
Gaussian	376
Legendre Transformations	377
7.10. Gaussian and Spherical Models	378
Gaussian Model	379
Spherical Model	382
Watson's Integrals Generalized	387
7.11. Magnetic Susceptibility in Gaussian and Spherical Models	389
7.12. Spherical Antiferromagnet	392
7.13. Spherical Model Spin Glass	395
Magnetic Properties of Spin Glass	399
7.14. Thermodynamics of Magnons	407
7.15. Magnetism in Two Dimensions	414
7.16. The XY Model: 1D	418
7.17. The XY Model: 2D	426
7.18. Transfer Matrix of Plane Rotator Model	433
Chapter 8. The Ising Model	438
8.1. High Temperature Expansions	441
8.2. Graph Theory	445
8.3. Low Temperature Expansions and the Duality Relations	448
8.4. Peierls' Proof of Long Range Order	452
8.5. 1D Ising Model in Longitudinal Fields	454
8.6. 1D Ising Model in Transverse Fields	462
8.7. Concerning Quadratic Forms of Fermion Operators	474
8.8. Two-Dimensional Ising Model: The Transfer Matrix	478
8.9. Solution of Two-Dimensional Ising Model in Zero Field	485

8.10.	Spontaneous Magnetization and Magnetic Susceptibility	494
8.11.	Zeros of the Partition Function	502
8.12.	Miscellania, Including 2D Antiferromagnets	507
8.13.	The Three-Dimensional Ising Model	517
8.14.	Ising Gauge Glass	526
8.15.	Frustration	528
Chapter 9. Miscellaneous Advanced Topics		533
9.1.	Critical Phenomena	533
9.2.	Green Functions Formalism	536
9.3.	Nonlinear Responses and Chaos	539
9.4.	Kondo Phenomenon: The s - d Model Redux	539
9.5.	Scaling, Renormalization and Information Theory	547
Bibliography		549
Index		561