
Contents

1	The Magnetic Susceptibility	1
1.1	The Magnetic Moment	2
1.2	The Magnetization	7
1.3	The Generalized Susceptibility	12
1.3.1	The Kramers–Kronig Relations	14
1.3.2	The Fluctuation-Dissipation Theorem	15
1.3.3	Onsager Relation	20
1.4	Second Quantization	21
1.4.1	Example: The Degenerate-Electron Gas	26
1.4.2	Example: The Zeeman Interaction	29
2	The Magnetic Hamiltonian	33
2.1	The Dirac Equation	33
2.2	Sources of Fields	35
2.2.1	Uniform External Field	35
2.2.2	The Electric Quadrupole Field	36
2.2.3	The Magnetic Dipole (Hyperfine) Field	41
2.2.4	Other Electrons on the Same Ion	43
2.2.5	Crystalline Electric Fields	44
2.2.6	Dipole–Dipole Interaction	50
2.2.7	Direct Exchange	51
2.2.8	Superexchange	58
2.2.9	Molecular Magnets	62
2.2.10	Double Exchange	65
2.2.11	Exchange on a Surface	66
2.3	The Spin Hamiltonian	67
2.3.1	Transition-Metal Ions	67
2.3.2	Rare-Earth Ions	75
2.3.3	Semiconductors	77

3	The Static Susceptibility of Noninteracting Systems	85
3.1	Localized Moments	85
3.1.1	Diamagnetism	88
3.1.2	Paramagnetism of Transition-Metal Ions	89
3.1.3	Paramagnetism of Rare-Earth Ions	91
3.2	Metals	94
3.2.1	Landau Diamagnetism	94
3.2.2	The de Haas–van Alphen Effect	98
3.2.3	Quantized Hall Conductance	102
3.2.4	Pauli Paramagnetism	106
3.3	Measurement of the Susceptibility	112
3.4	Local Moments in Metals	115
3.4.1	Virtual Bound States	116
3.4.2	Anderson’s Theory of Moment Formation	119
3.4.3	The Kondo Effect	124
4	The Static Susceptibility of Interacting Systems:	
	Local Moments	133
4.1	High Temperatures	135
4.2	Low Temperatures	146
4.3	Temperatures Near T_c	149
4.4	Landau Theory of Second-Order Transitions	153
4.5	Critical Phenomena	154
4.5.1	Order in 2D	155
4.6	Stoner-Wohlfarth Model	159
4.7	Dynamic Coercivity	162
4.8	Magnetic Viscosity	165
5	The Static Susceptibility of Interacting Systems: Metals	169
5.1	Fermi Liquid Theory	169
5.2	Heavy Fermion Systems	176
5.3	Itinerant Magnetism	177
5.3.1	The Stoner Model	177
5.3.2	The Hubbard Model	187
6	The Dynamic Susceptibility	
	of Weakly Interacting Systems: Local Moments	193
6.1	Equation of Motion	193
6.2	The Bloch Equations	197
6.3	Resonance Line Shape	202
6.3.1	The Method of Moments	202
6.3.2	The Relaxation-Function Method	206
6.3.3	Spin Diffusion	210
6.4	Spin Echoes	211
6.4.1	Measurement of T_1	211
6.4.2	Calculation of T_1	213

7	The Dynamic Susceptibility of Weakly Interacting Systems: Metals	219
7.1	Paramagnons	221
7.2	Fermi Liquid Theory	223
7.3	Conduction-Electron Spin Resonance	228
7.4	Spin Waves	230
7.5	Local Moments in Metals	231
7.6	Faraday Effect	235
8	The Dynamic Susceptibility of Strongly Interacting Systems	237
8.1	Broken Symmetry	237
8.2	Insulators	238
8.2.1	Spin-Wave Theory	240
8.2.2	Coherent Magnon State	248
8.2.3	Magnetostatic Modes	249
8.2.4	Solitons	250
8.2.5	Thermal Magnon Effects	253
8.2.6	Nonlinear Processes	255
8.2.7	Chaos	259
8.2.8	Optical Processes	262
8.3	High Temperatures	266
8.4	Micromagnetics	269
8.4.1	Magnetic Force Microscope	270
8.4.2	Phenomenological Damping	273
8.5	Metals	274
9	Thin Film Systems	281
9.1	Interfaces	281
9.1.1	Exchange Bias	281
9.1.2	Biquadratic Exchange	284
9.2	Trilayers	285
9.2.1	The RKKY Interaction	286
9.2.2	Quantum Well Model	289
9.2.3	Giant Magnetoresistance (GMR)	292
9.2.4	Tunneling	300
9.2.5	Spin Transfer	306
9.2.6	Spin Hall Effect	310
10	Neutron Scattering	315
10.1	Neutron Scattering Cross Section	315
10.2	Nuclear Scattering	317
10.2.1	Bragg Scattering	318
10.2.2	Scattering of Phonons	320

XII Contents

10.3 Magnetic Scattering	324
10.3.1 Bragg Scattering	328
10.3.2 Spin Dynamics	333
10.4 Example: Manganese Oxides	337
10.5 Example: Quantum Phase Transitions	341
References	345
Index	355