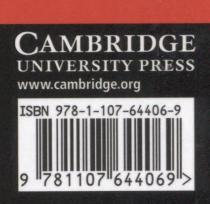
Since the advent of the nuclear reactor, thermal neutron scattering has proved a valuable tool for studying many properties of solids and liquids, and research workers are active in the field at reactor centres and universities throughout the world.

This classic text provides the basic quantum theory of thermal neutron scattering and applies the concepts to scattering by crystals, liquids and magnetic systems. Other topics discussed are the relation of the scattering to correlation functions in the scattering system, the dynamical theory of scattering and polarisation analysis. No previous knowledge of the theory of thermal neutron scattering is assumed, but basic knowledge of quantum mechanics and solid state physics is required.

The book is intended for experimenters rather than theoreticians, and the discussion is kept as informal as possible. A number of examples, with worked solutions, are included as an aid to the understanding of the text.

Gordon L. Squires (1924-2010) was a Lecturer in Physics at the University of Cambridge and a Fellow of Trinity College Cambridge from 1956. He published two other books with Cambridge University Press: Practical Physics and Problems in Quantum Mechanics with Solutions, wrote an article on quantum mechanics for the Encyclopaedia Britannica and contributed extensively to leading scientific journals. From his retirement in 1991 until his death in 2010, Dr Squires was the curator of the Cavendish Laboratory Museum and wrote a number of historical articles on scientists and scientific discoveries in Cambridge.



1	Introduction
.1	Basic properties of the neutron 1
.2	Numerical values for velocity, energy, wavelength 2
.3	Definitions of scattering cross-sections 5
.4	Scattering of neutrons by a single fixed nucleus 7
2	Nuclear scattering - basic theory
2.1	Introduction 10
2.2	Fermi's golden rule 10
2.3	Expression for $d^2\sigma/d\Omega dE'$ 13
2.4	Coherent and incoherent scattering 21
3	Nuclear scattering by crystals
3.1	Introduction 25
3.2	Normal modes 26
3.3	Probability function for a harmonic oscillator 27
3.4	Development of $\langle \exp U \exp V \rangle$ 28
3.5	Phonon expansion 30
3.6	Coherent elastic scattering 32
3.7	Coherent one-phonon scattering 43
3.8	Coherent multiphonon scattering 53
3.9	Incoherent scattering 54
3.10	Multiphonon cross-sections – approximation methods 57 Examples 59

4.1	Definitions of $I(\kappa, t)$ , $G(r, t)$ , and $S(\kappa, \omega)$ 61
4.2	Expressions for $G(r, t)$ and $G_s(r, t)$ 63
4.3	Analytic properties of the correlation functions 65
4.4	Principle of detailed balance 68
4.5	Scattering from a single free nucleus 70
4.6	Moments of the scattering function 73
4.7	Relation between elastic scattering and $I(\kappa, \infty)$ , $G(r, \infty)$
4.8	Static approximation 78
	Examples 84
5	Scattering by liquids
5.1	Introduction 86
5.2	No elastic scattering 87
5.3	Coherent scattering 88
5.4	Incoherent scattering 96
6	Neutron optics
6.1	Refractive index 110
6.2	Neutron reflection 114
6.3	Dynamical theory of scattering 116
	Examples 128
7	Magnetic scattering - basic theory
7.1	Preliminary results 129
7.2	Expression for $d^2\sigma/d\Omega dE'$ 131
7.3	Scattering due to spin only 137
7.4	Scattering by ions with spin and orbital angular momentum 139
7.5	Time-dependent operators 139
7.6	Cross-section for a paramagnet 143
	Examples 144
8	Scattering from magnetically ordered crystals
8.1	Elastic magnetic scattering 146
8.2	Scattering by spin waves 155
	Examples 169
9	Polarisation analysis
9.1	Introduction 171
9.2	Nuclear scattering 172

75

4 Correlation functions in nuclear scattering

Magnetic scattering 177
Bragg scattering from magnetically ordered crystals 181
Scattering by the atomic electric field 188
Examples 194
Appendices
The Dirac delta function 196
Fourier transforms 201
Some results for linear operators and matrix elements 204
Heisenberg operators 207
The harmonic oscillator in quantum mechanics 210
Angular momentum in quantum mechanics 215
Normal modes of crystals 218
The proofs of two results for magnetic scattering 226
Some mathematical results 229
Solutions to examples 231
Bibliography 241
References 243
Glossary of symbols 247
Index 255