

INDEX

- acoustic mode 222
- aluminium, scattering surface 47, 49, 234
- analysis of polarised neutrons 183–4
- angular frequency of normal mode 27, 219
- angular momentum operator 157, 215–17
- angular momentum in quantum mechanics 215–17
- angular width of Bragg peak 126–8
- anharmonic forces in crystal 52–3
- annihilation operator 27, 157, 210–12, 224–5
- antiferromagnet, elastic scattering 149–52
- approximation methods for multiphonon cross-sections 57–9
- argon, liquid, *see* liquid argon
- atomic constants, values 2
- Au₂Mn
 - neutron diffraction 152–5
 - scattering of polarised neutrons 187
- Biot-Savart law 130
- Bloch function 117
- Bloch theorem for harmonic oscillator 28, 212–13
- Boltzmann distribution 19, 232
- Born approximation 16, 83
- Borrmann fan 122–3
- bound scattering length 16
- box normalisation 12, 70–1
- Bragg geometry 127
- Bragg peak, angular width 126–8
- Bragg scattering
 - dynamical theory 116–28
 - magnetic: in antiferromagnet 149–52; ferromagnet 146–9, 182–5, 187–9; helimagnet 152–5, 187; paramagnet 144
 - methods of distinguishing nuclear and magnetic: in antiferromagnet 186; ferromagnet 147–8
 - methods of measuring 37–43
 - nuclear: in Bravais 32–5; non-Bravais crystal 36–7
 - nuclear and electric 193–4
 - nuclear and magnetic 181–9
 - polarisation effects 181–9, 193–4
- Bragg's law 32–4
- Bravais crystal 25
- Brillouin zone, first 27, 220–2
- Brillouin zone boundary 119
- Brockhouse, method of constant q 50–1
- Brownian motion 108–9
- classical forms of time-dependent pair-correlation functions 64, 70, 72
- closure relation 19, 205–6
- c-number 29
- cobalt, search for non-collinear spins 188
- coherent, incoherent scattering 21–4
- coherent scattering
 - elastic, *see* Bragg scattering
 - in liquids 88–96
 - multiphonon 31, 53–4
 - one-phonon 31, 43–53, 60
 - spin-state matrix elements 175–6

- coherent scattering length 24
 of hydrogen 115
 of silicon 125
- cold source 5
- compressibility, isothermal 90
- computer simulation of liquid
 properties 94–6
- conservation of energy 12, 14
- conservation of momentum 45, 71
- correlation functions
 in magnetic scattering 139–42,
 161–3, 167
 in nuclear scattering 61–84
- creation operator 27, 157, 210–12,
 224–5
- cross-section, scattering
 differential 6
 partial differential 6
 spin-state 171–2
 total 6
- de Broglie wavelength of neutron 3–5
- Debye–Scherrer cone 42–3
- Debye–Waller factor 34–7, 59, 143
 relation to $G_s(r, \infty)$ 78
- delta function 196–8
- density fluctuations 88–90
- density of states, phonon 35
 determination from incoherent
 scattering 55–6
- detailed balance, principle of 68–70,
 73
- differential scattering cross-section 6
- diffusion constant 103–9
 relation to frictional coefficient 108
 relation to velocity autocorrelation
 function 104
- dipole approximation 139
- Dirac delta function 196–8
- dispersion relations
 magnon 160–1
 phonon 46–52, 59, 219–20
- dispersion surface 119–22
- distribution, Boltzmann 19, 232
- dynamical theory of scattering
 for neutrons 116–28
 for X-rays 116
- elastic scattering
 absence of in liquids 87–8
 coherent nuclear 31–43, *see also*
 Bragg scattering
- elastic scattering—*cont.*
 incoherent nuclear 54
 magnetic 141, 146–55, *see also*
 Bragg scattering
 relation to $I(\mathbf{k}, \infty)$ and $G(r, \infty)$ 75–8
 electron spin density 138–9, 184–5,
 228
 vector operator 133, 143
- energy, conservation of 12, 14
- energy of crystal in terms of normal
 mode coordinates 59, 221, 223
- exchange integral 156
- extinction
 primary 125–8
 secondary 128
- extinction distance 126–7
- Fermi pseudopotential 15–16
- Fermi’s golden rule 11–12, 16
- ferromagnet, elastic magnetic
 scattering 146–9, 182–9
- Fick’s law of diffusion 103–4
- first Brillouin zone 27, 220–2
- flipper 172
- flipping ratio 184
- Foldy interaction 190, 192–4
- forces, interatomic in crystal
 anharmonic 52–3
 harmonic 26
- form factor
 magnetic 138–9, 147, 184, 228
 X-ray 193
- Fourier representation of periodic
 function 203
- Fourier transforms 201–3
- free scattering length 17
- Fresnel zone 112
- gadolinium, magnon dispersion
 relations 164–5
- Gaussian approximation 101–3, 106–7
- geometry, Laue and Bragg 127
- ghosts 46
- golden rule, Fermi’s 11–12, 16
- guide field 172
- guide tube 115
- hard-sphere potential 94–5
- harmonic forces 26
- harmonic oscillator
 correlation functions 84
 probability function 27–8, 212–14
 in quantum mechanics 210–14

- Heisenberg Hamiltonian 156
 in linear spin-wave theory 159–60
- Heisenberg operator 20, 207–9
- Heitler–London model 137
- helical spin ordering 152–5, 187
- Hermitian conjugate 204–5
- Hermitian operator 205
- Holstein and Primakoff operators 157
- hot source 5
- hydrogen, coherent scattering length 115
- incoherent approximation 57–9
- incoherent scattering 22
 elastic 54
 in liquid argon 96–7, 101–7
 in liquids 96–109
 one-phonon 55–6
 spin-state matrix elements 176–8
- incoherent scattering function 62–3,
 72–5, 85
 for liquids 96–7, 102–6
- integral representation of δ function for energy 18
- integrals, values of 230
- interactions between spin waves 168–9
- interference, nuclear and magnetic 185
- interferometer, neutron 110
- intermediate function 61–2, 66–8,
 75–8
 self 62: for liquids 101–7; single free nucleus' 71–2
- isothermal compressibility 90
- KMnF₃, magnetic Bragg scattering 150–2
- ladder operators 211, 216
- Lagrangian of crystal 223
- Landé splitting factor 139
- lattice, reciprocal 25
- lattice integrals 198–9
- lattice sums 198–200
- Laue geometry 127
- Laue method of measuring Bragg scattering 39–40
- Lennard-Jones potential 94–5
- linear approximation in spin-wave theory 157–8
- linear operators in quantum mechanics 204–6
- linear spin-wave theory 156–61
- liquid argon
 coherent scattering 92–4
 incoherent scattering 96–7, 101–7
 static pair-distribution function 93–4
 structure factor 92–3
 velocity frequency function 103, 109
- liquid binary alloys 96
- liquids 86–109
 coherent scattering 88–96
 incoherent scattering 96–109
- longitudinal terms in spin-correlation function 163
- LS coupling 137, 139
- magnesium, phonon frequencies 50–1
- magnetic dipole moment of neutron 2, 129
- magnetic field, affect on magnetic cross-sections 148, 165–6
- magnetic form factor 138–9, 147, 184, 228
- magnetic potential for neutron 129–31
- magnetic scattering
 elastic 141, 146–55, *see also* Bragg scattering
 inelastic 142, 155–70
 by ion with only spin angular momentum 137–8
 by ion with spin and orbital angular momentum 139
 by MnF₂ 180
 by paramagnet 143–5, 179–81
 spin-state matrix elements 177
- magnetic unit-cell 149–51
- magnetovibrational scattering 141–2, 166
- magnon 156
 dispersion relations 160–1
- mass, reduced 16–17
- mass expansion 58–9
- Maxwellian velocity spectrum for flux 2–4
- MnF₂
 magnetic scattering 180
 nuclear–magnetic interference 195
- MnTe₂, nuclear and magnetic scattering 152, 169
- moderating source 4–5
- moments of scattering function 73–5
- momentum, conservation of 45, 71

- multiphonon cross-sections,
approximation methods 57–9
multiphonon scattering, coherent 31,
53–4
- neutron
basic properties 1–2
currents in crystal 122–3, 128
density in crystal 123, 128
guide tube 115
interferometer 110
reflection 114–15
- nickel
incoherent scattering 176–7
spin density 185
values of n , γ_c 113–14
- non-Bravais crystal 36
coherent scattering 36–7, 46
incoherent scattering 56
magnetic scattering 137–8
normal modes 37, 222–3
nuclear and electric scattering 193–4
- non-collinear spins 186–9
normal modes of crystal 26–7, 218–25
acoustic, optic 222
dispersion relations 46–52, 59,
219–20
in non-Bravais crystal 37, 222–3
quantisation of 223–5
normalisation, box 12, 70–1
nuclear–magnetic interference 185,
195
- nuclear scattering, *see* Bragg scattering,
coherent scattering, incoherent
scattering, spin-state matrix
elements
- nuclear unit-cell 149
- nuclear unit-cell structure factor 37,
116–17, 182
- one-dimensional crystal, normal
modes 218–21
- one-magnon scattering 161–6, 170
- one-phonon scattering
coherent 31, 43–53, 60
incoherent 55–6
- operator
annihilation, creation 27, 157,
210–12, 224–5
Heisenberg 20, 207–9
ladder 211, 216
Pauli spin 129, 216–17
- operator—*cont.*
raising, lowering 215–16
scattering length 173–5, 181–2
Schrödinger, Heisenberg 207
thermal average of 20, 28, 206
optic mode 222
- optical phenomena with neutrons 110
- orbital magnetisation 134, 226–7
- ortho- and parahydrogen, total cross-
sections 194
- orthonormal functions 204
- pair-correlation function, time-
dependent, *see* time-dependent
pair-correlation function
- pair-distribution function, static 65,
82, 88
in liquid argon 93–4
- paramagnetic scattering 143–5,
179–81
separation from other diffuse
scattering 180–1
- partial differential scattering cross-
section 6
- particle density operator 65–6, 77–8,
85
- partition function 19
- Patterson function 77
- Pauli spin operator 129, 216–17
- Pendellösung phenomenon 123–5
length 125
- perfect gas, forms of $G(\mathbf{r}, t)$, $I(\mathbf{k}, t)$,
 $S(\mathbf{k}, \omega)$ 72
- perturbation theory, first order 16
- phonon 224
absorption, emission 43–53
density of states 35; determination
from incoherent scattering 55–6
dispersion relations 46–52, 59,
219–20
expansion 30–1
- Placzek
corrections 90–3
mass expansion 58–9
moments of scattering function 74–5
- polarisation 172
parallel to scattering vector 186
perpendicular to scattering
vector 182–5
- polarisation index of normal mode 27,
221
- polarisation spectrometer 172–3

- polarisation vector of normal mode 27, 221
determination of 52
- polared neutrons, production and analysis 183–4
- potential, interatomic 94–6
- potential, magnetic 129–31
- potential, nuclear 15–17
- powder method in Bragg scattering 42–3
- primary extinction 125–8
- principle of detailed balance 68–70
- probability function 27–8
of harmonic oscillator 27–8, 212–14
- production of polarised neutrons 183–4
- pseudopotential, Fermi 15–16
- RbMnF₃**, magnetic Bragg scattering 152, 185
- reciprocal lattice 25
- recoil energy 74
- reduced mass 16–17
- reflection of neutrons 114–15
- refractive index for neutrons 110–14, 118
- rocking curve 41
- rotation of crystal in Bragg scattering 41–2
- scattering, coherent, incoherent 21–4
- scattering function 62–3, 66–70, 82–3
incoherent 62–3, 72–5, 85
moments of 73–5
for single free nucleus 71–3
- scattering length 8
bound, free 16–17
coherent 24: of hydrogen 115; of silicon 125
- operator 173–5, 181–2
- sign 16
- values 9
- scattering surface 47, 49, 60
- scattering vector 15
- Schofield's prescription for $G(r, t)$ 70, 73, 102
- Schrödinger operator 207
- secondary extinction 128
- self intermediate function 62, 71–2, 101–7
- self time-dependent pair-correlation function 62–5, 72, 78, 84–5
classical form 64, 72, 84
- silicon Pendellösung fringes 123–5
scattering length 125
- single fixed nucleus, scattering from 7–9
- single free nucleus, scattering from 70–3
- spectrometer
polarisation 172–3
triple-axis 50–1
- spin angular momentum operator of electron 129–30
- spin density of electrons 138–9, 184–5, 228
determination of 184–5
vector operator 133, 143
- spin deviation 156–7
- spin-flip process 171, 176–80, 186–8
- spin magnetisation 134
- spin of neutron, precession through 2π 110
- spin-only scattering 137–8
- spin-orbit interaction (neutron-atom) 190–4
- spin-state cross-section 171–2
- spin-state matrix elements
magnetic interaction 177
nuclear and electric interactions 193
- nuclear interaction 175–6
- nuclear and magnetic interactions 182
- spin states of neutron 136, 171, 216–17
- spin states of nucleus–neutron system 23, 172–4
- spin waves
interactions between 168–9
linear theory 156–61
physical picture 166–8
scattering by 155–70
stiffness constant 161, 168–70
- square-well potential 16–17
- staggered spin in antiferromagnet 149, 152
- standard velocity for thermal neutrons 3
- static approximation 78–83
condition for validity 81–2

- static pair-distribution function 65, 82,
 88
 in liquid argon 93–4
stiffness constant for spin waves 161,
 168–70
structure factor 88–96
 limiting values 88–90
structure factor, nuclear unit-cell 37,
 116–17, 182
sum rules 75
sums, lattice 198–200
S-wave scattering 7

thermal average of operator 20, 28,
 206
time-dependent operator 20, 207–9
time-dependent pair-correlation
 function 62–8, 75–83
 classical form 64, 70, 72, 84
 for harmonic oscillator 84
 self 62–5, 72, 78, 84–5
 for single free nucleus (perfect
 gas) 71–2
time-of-flight apparatus 46
 spectrum 50
total scattering cross-section 6
 of ortho- and parahydrogen 194
transverse terms in spin-correlation
 function 163
triple-axis spectrometer 50–1

unit-cell, magnetic, nuclear 149
unit-cell, nuclear structure factor 37,
 116–17, 182
unit-cell vectors 25

vanadium
 flipping ratio in Bragg scattering 194
 incoherent scattering 176–8
 phonon density of states 56
velocity autocorrelation function
 98–100, 104, 108–9
velocity frequency function 99–103,
 108–9
velocity spectrum for flux 2–4

wavelength of neutron 3
wavevector of neutron 3
wavevector of normal mode 27, 221

X-ray scattering
 dynamical theory 116
 form factor 193
 from liquids 96
 static approximation 83