

## Index

- absolute temperature, 37
- absolute zero, 101, 162
  - and Fermi energy, 159, 161
  - and Fermi pressure, 162
  - and zero-point energy, 162
  - unattainability and the third law, 91, 101
  - variance of energy at, 85
- adiabatic
  - compressibility, 42
  - demagnetisation, 100, 102
  - process, 36, 99, 101
  - susceptibility, 44, 46
  - wall, 70, 72
- angular momentum, 139
  - orbital, 63, 64, 190, 195
  - spin, 63, 190, 210, 215
  - total, 63, 64, 97, 98, 190, 195
- antiferromagnetism, 188, 189, 195, 211–214, 234, 236
  - and Ising model, 236
- Avogadro's number, 15, 28, 29, 48, 123, 246, 309
  
- barometric law, 133, 302
- Bernoulli experiment, 5
- bifurcation, 206
- binary alloy, 234, 235, 238, 272
- binary mixture, 76, 272, 273, 275
- binodal line, 78
- binomial distribution, 5–8
- binomial theorem, 6, 92
- blackbody radiation, 55, 179–184
  - entropy, 186
  - pressure, 185
  - Rayleigh–Jeans law, 183
  - spectral energy density, 180
  - total energy density, 182
- Bloch wall, 203
- Bloch's law, 218
- Bohr magneton, 63, 94, 100, 207
- Boltzmann distribution, 131
- Boltzmann factor, 84, 125, 126, 134
- Boltzmann's constant, 33, 55
- Boltzmann's formula, 54, 55, 89, 96
- Bose gas, 153, 165–184
  - chemical potential, 155, 174
  - fugacity, 167, 168
  - mean energy, 154, 167
  - mean number of particles, 154, 167, 186
  - two-dimensional, 186
- Bose–Einstein condensation, 165, 167–170
- Bose–Einstein statistics, 153, 166
- Bosons, 149, 153, 155, 156, 165, 179
  - grand partition function, 153
  - occupation number, 153
  - wavefunction symmetry, 149
- Brillouin function, 98, 210
- Brillouin theory of paramagnetism, 97–99, 210
- Brillouin zone, 172, 173
- Brownian motion, 18, 303–309
  - Einstein formula, 309
  - Fokker–Planck equation, 312, 315
  - Langevin equation, 306, 319
- canonical distribution, 84, 85, 96, 145
- canonical ensemble, 54, 82–85, 114, 115, 119, 127
  - and thermodynamics, 88
  - definition of, 84
  - degenerate, 89, 113
  - energy fluctuations, 113
  - equation of state, 89
  - mean energy, 85
  - partition function, 84, 85, 88, 134, 155
- central limit theorem, 10, 18–19
- chemical potential, 34, 40, 61, 154
  - and Fermi energy, 164
  - and Gibbs free energy, 74, 247
  - and phase transitions, 76–77, 247, 255
  - of Bose–Einstein gas, 155
  - thermodynamic definition of, 61
- classical ideal gas, 116–133
  - chemical potential, 127
  - density of states, 116–119
  - entropy, 128
  - equation of state, 127
  - heat capacity, 128
  - Helmholtz free energy, 127
  - mean energy, 157, 185
  - partition function, 127
  - pressure, 184
  - specific heat, 128
- classical limit, 101, 103, 118, 155–156

- of quantum ideal gas, 157–159
- classical regime, 122–123, 125, 134, 147
  - validity criterion for, 129–130, 155
- classical statistical mechanics, 128, 145
- classical statistical physics, 183
- classical statistics, 128
- classical theories of phase transitions, 277, 279–287, 290, 295–296
- Clausius–Clapeyron equation, 77–79
- Clausius equation of state, 279
- coefficient of thermal expansion, 42, 278
- compressibility, 42
  - adiabatic, 42
  - isothermal, 42, 109, 110, 185, 238, 276, 281
- conductivity
  - electrical, 319
  - thermal, 320
- configurational integral, 134
- configurational partition function, 134, 136
- conjugate momentum, 139, 140
- conjugate thermodynamic variables, 57, 60–62, 73, 89, 90, 204
- continuum-states approximation, 84, 156–157
- correlation length, 276, 292, 296
  - critical exponent, 277
- correlations, 226, 240, 241, 312–314
- cosmic background radiation, 183–184
- counting of states, 50, 78, 83, 118, 122–123, 128, 156
- covariance, 13
- critical amplitudes, 274
- critical exponents, 30, 273–279, 297
  - definition of, 273–275
  - in phase transitions, 274
  - in random walks, 24
- critical field, 264
- critical fluctuations, 33, 314
- critical opalescence, 115, 273, 276
- critical point (liquid–vapour), 110, 272
  - opalescence, 110
- critical points, 78, 226, 272–279
- critical pressure, 280, 282, 296
- critical slowing down, 226
- critical temperature, 168, 171, 198–200, 223, 232–234, 238, 273, 280, 282, 296
  - two-dimensional Ising model, 289
- critical volume, 280, 282, 296
- critical wavelength, 168
- Curie constant, 99, 199, 207, 211
- Curie law, 99, 199
- Curie point, 271
- Curie temperature, 189, 199, 211, 273, 275, 276, 290
  
- De Broglie wavelength, 129, 130
- Debye theory of heat capacities, 103, 165, 174–179, 186
  - Debye frequency, 177
  - Debye frequency spectrum, 177
  - Debye function, 178
  - Debye temperature, 178–179, 320
- degeneracy
  - of microstate, 87, 91
  - of energy level, 83, 92, 147
  - of macrostate, 51
- degrees of freedom, 57, 128, 129, 145, 146, 214
  - thermodynamic, 77
- density of states, 116–119, 138–142
  - definition of, 85
  - for elastic waves, 175–177
  - for magnons, 218
  - for particles, 126
  - for photons, 180, 183
  - general case, 142
  - in phase space, 140
    - translational, 117–119, 141, 156, 157
- detailed balance, 224–225
- diffusion, 303, 304, 319, 320
  - definition of, 298
  - Einstein theory of, 304–305
  - equation, 299–300, 305
  - Fick’s law, 298, 320
  - in applied field, 301–303
  - statistical interpretation of, 304
  - types of, 298
- diffusion coefficient or diffusivity, 298, 305, 309, 313, 319, 320
- Dirac  $\delta$  function, 310, 317–318
- dispersion relation
  - for elastic waves, 172, 175
  - for spin waves, 216
- distribution function, 5, 50, 84, 110, 292, 300, 302
  - joint distribution function, 12–14
  - molecular orientational, 242, 244, 251, 253–255
- domains
  - ferromagnetic, 43, 202–203, 211, 276
  - nematic, 241, 262
- drift coefficient, 313, 315
- drift velocity, 301
- Dulong and Petit law, 104, 128
  
- Einstein
  - Brownian motion, 304, 309
  - diffusion, 304–305
  - theory of heat capacities of solids, 102–104
    - Einstein frequency, 103
    - Einstein temperature, 103
- elastic waves, 172–177
  - polarisation modes, 175
- electric moment, 34
- electric susceptibility, 46, 261
- electrons, 188–196, 207

- electrons in metals, 319, 320
  - chemical potential, 159
- ensemble, 49–53
  - definition of, 1, 49
  - in phase space, 142–145
  - thermodynamic equivalence of ensembles, 112–113, 155–156
- ensemble average vs time average, 50
- ensemble probability, 2, 20
- enthalpy, 46, 114, 286
  - and Legendre transforms, 73
- electric, definition of, 46
- magnetic, definition of, 44
- natural variables of, 38
- thermodynamic definition of, 38
- entropy, 80, 223, 286
  - and equilibrium conditions, 35, 56
  - and the second law, 35
  - and the third law, 37, 91, 101
  - as a measure of disorder, 37, 79, 96
  - in canonical ensemble, 87–89
  - in grand canonical ensemble, 106
  - in isothermal–isobaric ensemble, 111
  - in microcanonical ensemble, 54
  - magnetic, 99, 101, 102
  - of classical ideal gas, 128
  - of electromagnetic radiation, 186
  - statistical definition of, 54, 87, 89
  - thermodynamic definition of, 35
- entropy change, 62, 80, 87, 96
  - at phase transitions, 78, 250, 270, 271
- equal a priori probabilities postulate or second postulate, 52
- equation of state, 33, 36, 37, 114
  - canonical, 38, 89
  - classical ideal gas, 127, 280
  - Clausius, 279
  - definition of, 33
  - electric, 45, 148
  - general, 108
  - grand canonical, 40
  - isentropic–isobaric, 38
  - isothermal–isobaric, 39
  - magnetic, 43, 93, 97
  - microcanonical, 37, 60, 62
  - real gas, 136
  - Van der Waals, 280–286, 296
- equilibrium conditions
  - equilibrium with respect to particle exchange, 61
  - general, 68–70
  - in isolated system, 55–61
  - in isolated system at  $P$ , 72
  - in phase space, 145
  - in system at  $T$  and  $V$ , 71
  - in system at  $T$  and  $P$ , 71
  - mechanical equilibrium, 60
  - phase equilibria, 75–77
  - thermal equilibrium, 56–60
- equipartition of energy, 128
- equipartition theorem, 128, 129, 145–148
- ergodic hypothesis or first postulate, 50, 53, 307
- error function, 319
- exchange coefficient, 194, 195, 207
- exchange integral, 193, 194
- extensive variables, 16, 33, 34, 45, 74, 122, 127, 128
- external parameters, 34, 37, 86
- Fermi–Dirac distribution, 161, 165
  - mean energy, 154, 162, 185
  - mean number of particles, 154
- Fermi–Dirac function, 159, 160
- Fermi–Dirac statistics, 161
- Fermi energy, 185
- Fermi gas, 153–165
  - chemical potential, 164
  - degenerate, 159, 160
- Fermi energy, 159, 161, 163
- Fermi pressure, 162, 185
- Fermi sphere, 162
- Fermi temperature, 159, 163
- Fermi velocity, 320
- fermions, 149
  - grand partition function, 152
  - occupation numbers, 153
  - wavefunction symmetry, 149
- ferrimagnetism, 188, 211–214
- ferromagnetism, 188, 196–211, 275
  - and exchange interaction, 190–195
  - and Heisenberg model, 189–196
  - and Ising model, 196, 220, 223–234, 237, 287
- first Brillouin zone, 172, 173
- first law, 35, 71, 72
- fluctuation-dissipation relations, 42, 112
  - Brownian motion, 309, 313
  - fluids, 59, 86, 109, 238
  - generalised, 90
  - magnetic, 94, 233
- fluctuation-dissipation theorem, 59
- fluctuations, 80, 223, 251, 292, 296, 315, 316
  - critical, 33, 199, 273
  - density or particle number, 108–110
  - energy, 113
  - order parameter, 230, 276, 292
  - pressure, 90, 114
  - relative, 5, 7, 8, 15, 16, 29, 59, 186
  - volume, 111–112
- Fokker–Planck equation, 309–317
  - steady-state solution, 314–317
- free electron gas, 147, 162–165, 185
- free expansion of a gas, 137–138
- Frenkel defect, 79
- friction, 301, 302, 306–309, 314–317

- function of state, 35, 36, 38, 39, 41
- fundamental thermodynamic relation, 36–40, 73  
 general form, 62  
 in canonical ensemble, 88  
 in electric systems, 45, 46  
 in grand canonical ensemble, 107  
 in magnetic systems, 43, 44, 204  
 in microcanonical ensemble, 62
- gamma function, 25, 26
- gas constant, 309
- Gaussian distribution, 8–12, 19, 30, 58, 59, 131, 132, 254, 300, 302, 315
- generalised coordinates, 34–37, 89, 128, 146
- generalised forces, 34, 36–37, 40, 62, 89
- generalised potential, 315–318
- Gibbs free energy, 46, 207–293, 295  
 and chemical potential, 40  
 and Legendre transforms, 73  
 and phase transitions, 74–75, 77, 247, 255, 270, 271  
 electric, definition of, 46  
 magnetic, 46  
 magnetic, definition of, 44  
 statistical definition of, 111  
 thermodynamic definition of, 39, 111
- Gibbs–Duhem relation, 74, 77
- Gibbs paradox, 128
- Gibbs phase rule, 76–77
- grand canonical distribution, 106
- grand canonical ensemble, 104–110, 115, 237  
 and thermodynamics, 106–108  
 definition of, 105, 106  
 particle number fluctuations, 108–110
- grand canonical partition function or grand partition function, 106, 122, 155  
 definition of, 106
- grand canonical potential or grand potential, 106, 107
- Hamiltonian, 74, 128, 142, 144–146, 149, 296  
 dipolar interaction, 196  
 effective (magnetic mean field), 196, 197  
 electrostatic interaction, 192, 194  
 exchange, 195, 196  
 Heisenberg, 195–196, 214  
 of Ising model, 223, 292, 293  
 real gas, 133
- harmonic oscillator  
 classical, 114  
 quantum, 102, 114, 147, 171–174, 217
- heat, 32, 34–36, 40, 59, 63, 69, 72, 82  
 statistical interpretation of, 63
- heat and particle reservoir, 104–110
- heat and pressure reservoir, 110–112
- heat capacity, 59, 114, 138  
 and the third law, 86  
 at constant pressure, 41  
 at constant volume, 41, 59, 86, 104, 114
- electric, 45  
 magnetic, 43, 44, 47, 208–209, 232, 234  
 of conduction electrons, 102, 165, 166  
 of gases, 128  
 of lattice vibrations of solids, 102, 103, 171–179, 186  
 of paramagnetic solid, 94, 99–101, 114  
 thermodynamic definition of, 40
- heat conductivity, 320
- heat or temperature reservoir, 59, 69–71, 82–92, 113, 145, 305
- Heisenberg model, 196
- helium  
 gas, 130, 147  
 liquid, 100, 169  
 superfluid, 290, 295
- Helmholtz free energy, 46, 79, 80, 97, 114, 204–208, 218, 249, 250, 254–257  
 and Legendre transforms, 73  
 and phase transitions, 222, 223, 271, 272, 279  
 electric, definition of, 46  
 magnetic, definition of, 44  
 of classical ideal gas, 127  
 of classical real gas, 136  
 of Ising model, 289  
 of Van der Waals gas, 284  
 statistical definition of, 88  
 thermodynamic definition of, 38
- hysteresis, 43, 202–203, 211
- ideal gas temperature, 33, 37
- identical particles, 93, 119, 151, 165  
 indistinguishability and symmetry of wavefunction, 120, 150, 151, 166
- infinitesimal process, 36, 40, 62, 63, 88
- intensive variables, 33, 34, 40, 45, 57, 61, 74, 77, 122, 127
- internal energy, 35, 44, 46, 53, 54, 59, 73, 82, 85–87, 111, 124, 137, 186, 233, 289, 290
- irreversible process, 35, 62, 63, 68, 137, 203, 317–320
- Ising model, 220–238  
*d*-dimensional, 292–295  
 one-dimensional, 221–223  
 three-dimensional, 277  
 two-dimensional, 277, 296  
 Monte Carlo simulation, 224–234  
 Onsager solution, 223, 287–290
- isotherm, 78, 283, 284  
 critical isotherm, 204  
 exponent, 277, 278, 282  
 Van der Waals, 281, 283
- isothermal  
 compressibility, 42  
 susceptibility, 44, 46
- isothermal–isobaric ensemble, 110–111  
 and thermodynamics, 111

- definition of, 111
- volume fluctuations, 111–112
- Joule coefficient, 137, 138
- Joule–Thomson effect, 138
- Kelvin temperature scale, 33
- kinetic theory of gases, 185
- Lagrangian, 74
- Landau–Peierls argument, 222–223
- Landau theory of phase transitions, 287
  - magnetic, 203–211, 287
  - nematic liquid crystals, 256–259, 267, 287
  - validity, 259, 290, 295
- Langevin equation, 305–309, 311, 313–314, 319
- Langevin formula for electric susceptibility, 148
- latent heat, 79, 81, 250, 267
  - at critical point, 272
  - continuous transition, 290
  - first-order transition, 270
- lattice, 20, 21
  - constant, 215
  - cubic, 218
  - dimensionality, 23, 24, 261
  - gas, 234–238
  - of spins, 63, 120, 188, 190, 211, 215, 223, 224
  - point defects, 79
- law of large numbers, 5, 20, 225
- Lebwohl–Lasher model, 259–266
- Legendre transformations, 72–74, 107, 112
- Liouville’s theorem, 142–145
- liquid crystal
  - calamitic, 240
  - director, 240
  - discotic, 241
  - order parameter, 242–244, 247–250, 255, 257, 258
    - in Landau theory, 258, 259
    - in Lebwohl–Lasher model, 264, 266
    - in Maier–Saupe theory, 245–246
    - in Onsager theory, 253–254
    - long-range (in simulations), 260
    - short-range, 260
  - phases, 239–241
    - cholesteric, 241
    - columnar, 241
    - nematic, 240
    - smectic, 241
- liquid–vapour transition, 78, 272–273, 276, 290
- local field, 63, 64, 92, 101, 188, 195–197, 207
- macrostate, 49–53, 64, 151
- magnetic cooling, 99–101
- magnetic dipolar interaction, 189, 196
- magnetic energy, 93, 95, 99, 202, 225
- magnetic equation of state, 93
- magnetic moment, 34, 93, 95, 98, 100, 195–198, 204, 210, 213, 215, 218, 225, 233, 245, 276, 290
  - per lattice site, 223, 231, 237
- magnetic susceptibility, 44, 94, 99, 114, 199, 211, 230, 232–234, 238, 261
- magnetisation, 211
  - critical exponent, 275, 293
  - definition of, 44, 94, 98, 197
  - Ising model, 230
  - paramagnetic, 98, 214
  - saturation, 98–100
  - spontaneous, 188, 211
  - total, 212, 213
- magnons, 214–218
- Maier–Saupe theory of the isotropic–nematic phase transition, 242–251
  - entropy, 246, 248
  - Gibbs free energy, 247
  - Helmholtz free energy, 246, 248
  - internal energy, 246
  - order parameter, 245–246, 248, 250
  - orientational distribution function, 245
  - orientational mean field, 244
  - pseudopotential, 244
  - thermodynamic stability, 246–248
- marginal density, 13, 131
- Markov chain, 224
- Markov process, 304
- master equation, 224
- Maximum entropy principle, 56, 70
- Maxwell distribution, 131, 158, 315
- Maxwell velocity distribution, 132
- Maxwell’s construction, 281, 283, 284
- Maxwell’s relations, 37–40
  - for electric systems, 45
  - for fluids, 39, 108
  - for magnetic systems, 43
- Maxwell–Boltzmann distribution, 130–132, 147
- Maxwell–Boltzmann partition function, 123
- Maxwell–Boltzmann statistics, 119–122, 155
- Mayer function
  - lyotropic liquid crystals, 251, 252
  - real gas, 135
- mean-field approximation
  - for ferromagnet, 196, 197, 208, 218, 245
  - for nematic, 244, 245
  - Van der Waals equation of state as, 285–286
- mean free path, 17, 163, 319, 320
- mean square radius, 17
- mean value, 3, 14, 58, 131, 292, 305
  - binomial distribution, 6
  - Gaussian distribution, 11
- mechanical equilibrium, 71, 72
- mesophases, 239–241
- Metropolis algorithm, 224–227, 262
- microcanonical ensemble, 53–54, 89, 113, 145

- and equilibrium conditions, 55–56, 68
- and thermodynamics, 54–55
- definition of, 53
- microstate, 49–53, 55, 56, 82–85, 105–106, 111, 119–121, 128, 129, 145, 149–153
- Minimum energy principle, 70
- molecular internal partition function
  - rotational problem, 147
  - vibrational problem, 147, 148
- Monte Carlo simulations
  - Ising model, 224–234, 290
  - Lebwohl–Lasher model, 259–266
  - random walk, 19–24
- most probable state, 56
- most probable value, 3, 58, 292, 315
  
- Néel temperature, 214
- normal modes, 173
- nuclear magnetic resonance, 66
  
- Occupation number, 119, 121, 122, 151, 153
  - and distinguishability, 120
  - and energy, 122, 151, 174
  - fermions, 160, 161, 163
  - grand canonical ensemble, 122
  - in classical regime, 129
  - Maxwell–Boltzmann statistics, 120
- Onsager theory of the two-dimensional Ising model, 223, 231, 287–290
- Onsager theory of the isotropic–nematic phase transition, 251–256
  - entropy, 252–253, 255, 256
  - excluded volume, 252–253
  - Helmholtz free energy, 252, 255–257
  - order parameter, 253–255
  - orientational distribution function, 254, 255
  - second virial coefficient, 251, 252
- order of a phase transition, 270–272
- order parameter
  - at first-order phase transition, 208, 317
  - correlation length of, 276, 292
  - critical exponent, 200, 275, 277, 278, 283
  - finite-size effects on, 234
  - fluctuations of, 276, 292, 295
  - in Landau theory of phase transitions, 207, 275, 287
  - lattice gas, 237
  - magnetic, 200, 206, 210, 231, 232, 238, 275, 290, 295
  - nematic, 242
  - of fluids, 275
  - on critical isotherm, 277
- paramagnetic–ferromagnetic transition, 270
- paramagnetism of localised spins, 63–67, 80, 91–99, 188
  - entropy, 65–67, 94, 96
  - heat capacity, 94, 99, 101
- magnetisation, 94, 98
- mean energy, 93, 95
- mean magnetic energy, 93
- mean magnetic moment, 93, 95, 100
- susceptibility, 94
- variance of the energy, 93
- variance of the magnetic moment, 94
- partition function, 112
  - canonical, 84, 85, 88, 155, 158
  - configurational, 134–136
  - grand canonical, 106, 111, 122, 152, 153, 155
  - for Ising model
    - one-dimensional, 221, 222
    - two-dimensional, 288, 289
  - isothermal–isobaric, 110, 111
  - of classical ideal gas, 120, 127
    - in classical regime, 122–123
  - of localised spins, 92
  - of phonons, 174
  - of photons, 183, 186
  - of real gas, 134
  - of single harmonic oscillator, 103, 114
  - of single particle, 97, 124–126, 155, 158
    - grand canonical, 152
    - in an external field, 124
    - internal, 124, 147
    - translational, 124, 126, 157
  - of Van der Waals fluid, 286
- Pauli exclusion principle, 129, 189, 286
- phase equilibria, 74–77, 79
  - general, 74–75
  - Gibbs phase rule, 76
  - in isotropic fluids, 75
- isotropic–nematic liquid crystals, 247, 248, 256, 258, 260, 267
- normal–superconductor, 273
- normal–superfluid, 290, 295
- paramagnetic–ferromagnetic, 189, 198, 200, 203, 208, 211, 271
- phase space, 48, 116, 138–145
- phase transitions, 33, 74–79, 133, 167, 189, 198–200, 203, 207, 208, 222, 226, 236, 241, 269–270, 315, 316
- phonon gas, 171–179
  - mean energy, 177
  - mean occupation number, 174
  - partition function, 174
- photon gas, 179–183
  - density of states, 180
  - mean occupation number, 183
  - partition function, 183
- Planck statistics, 155, 174, 183, 186, 217
- Planck’s constant, 55, 63, 134, 182, 217
- Planck’s law, 180
- Poisson brackets, 144

- Poisson distribution, 12
- polymer chain, 17, 19, 20, 22, 31, 80  
elasticity, 80
- polymer liquid crystal or liquid crystal polymer, 240
- postulates of statistical physics, 49–53  
Equal a priori probabilities postulate or Second Postulate, 52  
Ergodic hypothesis or First Postulate, 50, 53
- pressure  
fluctuations, 90, 114  
microscopic interpretation of, 48  
of blackbody radiation, 185  
of classical ideal gas, 127, 184  
standard atmospheric, 147  
thermodynamic definition of, 36
- probability density function, 3  
joint probability density, 13  
marginal density, 13
- probability mass function, 3
- quantum ideal gas, 149–186  
mean energy, 154, 157, 177, 185  
mean number of particles, 154, 156, 158, 167, 186  
mean occupation number, 153, 159–161, 163, 174, 183
- quantum states, 51, 57, 62, 82, 86, 129, 140–142  
of free particle, 117–119, 154, 185  
of harmonic oscillator, 102, 171–174, 217  
of magnetic moment, 97, 99
- quantum statistics, 151–155
- quasi-static process, 33, 36, 61–90
- Quenching of orbital angular momentum, 195, 198
- random force, 306, 309–310, 312
- random variable, 3–151  
continuous, 262  
deviation from the mean, 4  
discrete, 3  
distribution function of, 3  
equal in distribution, 3  
joint distribution function of, 13, 131  
mean value of, 3  
moments of, 4  
most probable value, 3  
relative fluctuation of, 5  
standard deviation of, 5  
statistically independent, 2, 14, 131  
variance of, 4  
variance of the sum, 14
- random walk, 1, 80, 94, 224, 303, 309  
biased, 17, 30  
effective displacement, 8  
generalised, 12–24  
Monte Carlo simulations, 19–24, 30  
self-avoiding, 22–24, 30  
simple, 5, 12, 30
- Rayleigh–Jeans law, 183
- real gas, 133–138  
configurational partition function of, 134  
equation of state, 136, 279  
intermolecular potential, 137, 138, 286  
Mayer function, 135
- relaxation time, 227, 320  
spin–lattice, 66  
spin–spin, 66
- renormalisation, 278, 296
- representative sample, 224
- reservoir, 69, 74  
heat and particle, 104–110  
heat and pressure, 71, 110–112  
heat or temperature, 59, 70–71, 91, 305  
pressure, 69, 72
- response function, thermodynamic, 40–46, 59, 94, 199, 276
- reversible process, 33, 35, 36, 41, 62, 63, 68, 70, 71, 79, 99, 101, 102
- saturation magnetisation, 189, 198, 199, 207, 211, 218
- saturation transition, 262, 264
- Scattering of light, 110, 273
- Schottky anomaly, 101
- second law, 35, 68, 298  
Planck's formulation of, 60  
statistical interpretation of, 56, 68
- Second virial  
approximation, 137, 251  
coefficient, 137–138, 251, 253, 296  
of hard cylinders, 254  
of real gas, 136, 138
- single-particle partition function, 152, 155, 158
- Sommerfeld expansion, 164
- sound waves, 174–177
- specific entropy, 79
- specific heat, 320  
critical exponent, 276–278, 284, 285, 290  
definition of, 40  
magnetic, 218, 276  
molar, 147, 148  
of free electron gas, 165, 320  
of ideal gas, 128  
of Ising model, 289  
of Lebowitz–Lasher model, 261  
of solids, 104, 128, 178, 186  
of water, 81  
per lattice site, 234, 235, 238
- specific volume, 79
- spin quantum number, 190
- spin–statistics connection, 149
- spin waves, 214–218
- spontaneous magnetisation, 199–200, 211, 222–287
- standard deviation, 5, 7, 8
- state function, 35, 36, 38, 39, 41
- statistical ensemble, 1, 20

- statistical weight, 51, 54–57, 64, 65, 83, 92, 96, 113  
 steady state, 301, 313–319  
 Stefan–Boltzmann constant, 182  
 Stefan–Boltzmann law, 182, 186  
 Stirling’s formula, 9, 28–29, 65, 67  
 Stokes’s law, 309  
 superfluid liquid helium, 169  
   normal–superfluid transition, 290, 295  
 susceptibility  
   adiabatic, 44, 46  
   critical exponent, 199, 209, 276, 294  
   electric, 46, 148, 261, 264  
   isothermal, 44, 46, 90, 233–234  
   magnetic, 44, 94, 99, 114, 199, 232–234, 238, 261  
     of antiferromagnet, 214  
     of ferrimagnet, 213  
 temperature, absolute, 33, 36, 56, 60, 159  
   ideal gas scale, 33, 37, 127  
   Kelvin scale, 75  
   negative, 57, 59, 65–66, 85, 114  
   statistical definition of, 57  
   temperature, microscopic interpretation of, 48  
 thermal energy, 84, 125, 129, 156, 159, 272  
   at room temperature, 100  
 thermal equilibrium, 33, 34, 56–61, 69, 71, 79, 84,  
   114, 116, 307, 313  
 thermal radiation, 179  
 thermal vibrations of the crystal lattice, 163, 165,  
   171–179  
   Debye theory, 174–179  
   Einstein theory, 102–104  
 thermal wavelength, 129–130, 134, 167, 168  
 thermodynamic potentials, 37–40, 72, 112  
   and equilibrium conditions, 72–74  
   and phase transitions, 270  
 thermodynamic process, 33  
 thermodynamic system, 32  
 thermometer, 33  
 thermostat, 69  
 third law of thermodynamics, 37, 41, 86, 91, 101, 104  
 transfer matrix, 221–222, 288  
 triple point, 75, 78  
   of water, 33, 75, 77  
 ultraviolet catastrophe, 183  
 universality class, 24, 277, 292  
 Van der Waals theory of the liquid–vapour transition,  
   279–286  
   critical exponents, 282–285  
   equation of state, 279–282  
   intermolecular potential, 285  
 variance, 4, 8  
   binomial distribution, 7  
   Gaussian distribution, 11  
 virial  
   coefficient, 136, 296  
   expansion, 136  
 viscosity, 309  
 volume change at phase transitions, 270  
 Weiss domains, 202  
 Weiss’s mean-field theory of ferrimagnetism and  
   antiferromagnetism, 211–214  
 Weiss’s mean-field theory of ferromagnetism or Weiss  
   model, 190, 196–204, 207, 208, 210, 218, 245,  
   277, 287  
   Curie constant, 211  
   Curie–Weiss law, 199  
   magnetisation, 211  
   Weiss parameter, 197, 207  
 Wiedemann–Franz law, 320  
 Wien displacement law, 181, 182  
 Wien’s law, 183  
 work, 33–36, 62, 63, 70, 71, 87–89  
   electric, 45, 46  
   magnetic, 43–44, 97  
   mechanical, 33, 36, 69, 82  
 Zeeman energy, 63  
 zero-point energy, 103  
 zeroth law, 33