

---

## INDEX

---

- abelian group, 430
- absorption, coefficient, 196
- accelerated charge, 226
- acceptor, 359
- actinide, 299, 366
- action and reaction, 11
- action-angle variable, 64, 65
  - harmonic oscillator, 65
- adiabatic:
  - demagnetization, 132, 133
  - gas law, 113, 114
  - invariant, 186
- Ag, 344
  - magnetic moment, 168
- alpha particle,  $\alpha$ , 371
  - decay, 373, 374
- amplitude modulated (AM), 201, 203
- angular momentum, 13, 38, 243, 244
  - addition, 258
  - Chapter 17, 242
  - commutator, 245
  - conserved, 14
  - eigenvalue, 246
  - magnetic moment, 168
  - matrix, 256–258
  - orbital, 246
  - spin, 246
  - total, 247
    - nucleus, 369
    - wave function, 249
- anion, definition, 301
- antibaryon, 384
- antineutrino, 373, 384
- antiparticle, 384
- antiquark, 380, 385
  - parity, 389
- aphelion, 17
- apogee, 17
- As, 358
- asymmetric stretch vibration mode, 48, 49
- asymmetry parameter, 163
- atom, size, 299
- atoms, Chapter 21, 290
- attitude, 31
- attractor, 79
- Au, 344
- Avogadro's number, 320
- axial vector, 34, 35

- band:
  - conduction, 341, 359
  - energy, 341
  - two dimensions, 354
  - valence, 341, 359
- bank, 31
- baryon, 380
  - charmed, 396
  - decimet, 391
  - ground state octet, 390
    - characteristics, 392
  - number,  $B$ , conservation, 393
  - orbital angular momentum, 393
  - parity, 391
  - quantum number, 384
  - SU(3) decomposition, 390
  - three quarks, 390
- basis vectors, 472
- beauty quark,  $b$ , 395, 398
- Bell state, 478, 479
- Bessel:
  - equation, 440, 444, 450
  - function, 450
    - asymptotic, 453
    - modified, 454, 455
    - modified, spherical, 456
    - potential problem, 154
    - roots, 452
    - spherical, 268, 456
  - functions, figure, 451
  - generating function, 450
  - integral representation, 450
  - recursion relations, 454
- beta,  $\beta$ :
  - decay, 302, 374, 376, 384
  - function, 466
  - particle, 371
- Bi, 374
- bifurcation, 76, 77
- binary numbers, 472
- binding energy per nucleon, 368
- Biot-Savart law, 157
- bit, 471
- black body radiation, 139
- black hole, 366
- Bloch law for resistivity, 346
- Bohr radius, 291
- Boltzmann:
  - factor, 125, 126
  - ratio, 126
- boost, 178
  - parameter, 90
  - velocity, 98
- boron, 359, 374
- Bose-Einstein (BE):
  - condensation, 138
  - distribution, 137
  - statistics, 136, 138, 139
- boson, 380
- bottom quark,  $b$ , 398
- boundary conditions:
  - between media, 147, 148
  - Cauchy, 153, 154
  - Dirichlet, 153, 154
  - electromagnetic, 147, 148
  - mixed, 153, 154
  - Neumann, 153, 154
- Bragg's law, 333
- Bravais lattice, 328, 329
- Bremsstrahlung, 239, 240
- Brewster's angle, 194, 211
- Brillouin:
  - function, 131
  - zone, 336, 347, 421
    - linear chain, 52
    - one dimension, 348
    - two-dimensional, symmetry points, 356, 357
- Brownian motion, 324
- bulk modulus, 44
- C-14 half-life, 377
- Ca, 369
- canonical:
  - ensemble, 125
  - equations of Hamilton, 7
  - momentum, 14, 60
  - transformation, 59, 60
    - definition, 60
    - generating function, 60
    - harmonic oscillator, 61
- carbon:
  - cycle, 378
  - dating, 377, 378
- Carrot cycle, 105
  - figure, 106, 107
- carrier frequency, 202, 203
- catalyst, 378

- cation definition, 301
- Cauchy integral formula, 426
- Cauchy-Riemann conditions, 425
- Cayley Klein parameter, 410
- center:
  - of gravity, energy splittings, 248
  - of mass, 13, 29
  - of momentum, 13
- central force, Chapter 2, 10, 12
- centrifugal:
  - distortion, 56
  - force, 37, 325
- chaos:
  - mixing, 73
  - onset, 81
  - properties, 73, 78
- characteristic impedance, 146, 190, 200, 201
- charge:
  - accelerated, 226
    - relativistically, 227–229
  - conjugation, 100
- distribution:
  - energy, I 65
  - torque, 165
  - electric, 383
  - elementary particle, 384
  - motion in crossed E and B fields, 185
  - quark, 385
  - radiation, 220
  - spiraling motion, 186
  - strong, 79, 383, 395
  - uniform motion, 224, 225
  - weak, 383
- charm,  $C$ , 384
  - quark,  $c$ , 387, 395, 434
- Chebyshev:
  - equation, 441
  - generating function, 457
  - polynomial, 457
- chemical potential, 128
- Cherenkov:
  - angle, 230–232
  - radiation, 230–232
- Cl, 341
- class, 431
- classical statistics approximation, 342
- Clausius statement, 104
- Clausius-Clapeyron equation, 110, 111, 323
- Clebsch Gordan coefficient, 249–254, 261
- close packing, 330
- Co, 374, 376
  - decay, 374
- collision, 24
  - Chapter 16, 233
  - Coulomb, 234–238
  - impact parameter, 235–238
  - scattering angle, 237, 238
  - with nucleus, 237, 238
- color of quark, 395
- column vector, 476
- commutator, 245
  - angular momentum, 245
  - linear momentum, 245
- complex variables, 425
- compressibility, 44
- Compton wavelength, 204
- condensation, Bose-Einstein (BE), 138
- conduction:
  - electron specific heat, 115
  - medium, 197
  - solids, Chapter 24, 340
- conductivity:
  - AC, 344, 345
  - electrical, 342, 343
  - thermal, 346
- conjugate momentum, 5, 184
  - charge in electromagnetic field, 6
  - Kepler problem, 6
  - symmetric top, 6
- conservation laws of elementary particle
  - interactions, 393
- conservative system, 16
- constraint:
  - holonomic, 4, 5
  - pseudoholonomic, 5
- contour integration, 427–429
- contraction of tensor, 179
- contravariant, 414
  - tensor, 177
- coordinate:
  - cyclic, 14
  - generalized, 45
  - system, 402
    - cartesian, 403
    - cylindrical, 404, 405
    - rotation, 36
    - spherical polar, 405–407
- Coriolis force, 37, 38

- correlation time, 327
- corundum, 331
- cosine Fourier transform, 419
- Coulomb:
  - collision, 234–238
  - force, 364
  - integral, 305
  - law, 2, 152, 169, 364
  - potential, 267
  - self-energy, 239
- coupling:
  - jj* type, 247
  - Russell Saunders, 247
- covariant, 414
  - tensor, 177
- CPT invariance, 100
- critical:
  - angle, 191
  - isotherm, 321
  - point, 321
- cross section:
  - differential, 22, 318
  - partial wave, 318
  - phase shift, 318
  - scattering, 22, 23, 238, 241
  - total, 318
- crystal:
  - lattice, 327
  - plane, 332
  - radii, 301, 302, 303
  - structure, 332
  - system, 327, 432
- crystallography, 432
- Cu, 344
- cubic, 327–329
  - unit cell, 330
- current, probability, 265
- cutoff wavelength, 200
- cyclic coordinate, 14
- cylindrical coordinates, 404
  
- d'Alembertian, 97
- damping:
  - constant, 197
  - force, 197
  - frictional, 344
- Debye:
  - frequency, 54
  - relaxation, 327
  - specific heat, 54, 114, 130
  - temperature, 54, 346
- decay, radioactive, 372
- decimal number, 472
- decimet, 391
- degeneracy:
  - energy, 126
  - perturbation theory, 312
- degree of freedom, 109, 110
  - translational, 43
- delocalized:
  - electron, 342, 357, 358
  - hole, 357, 358
- delta:
  - function,  $\delta(x)$ , 420, 467, 468
    - Dirichlet form, 468
    - Fourier form, 468
    - Gaussian form, 468
    - Lorentzian form, 468
  - particle,  $\Delta$ , decay, 393
- demagnetization:
  - adiabatic, 132, 133
  - factor, 172–174
- density matrix, 479, 480
- density of states:
  - electron, 351, 352
  - mass, 354
  - free electron band, 349
  - phonon, 114
- depolarization factor, 172
- descent of symmetry, 435
- determinant, 407
- deuteron, 378
- diamagnet, perfect, 339
- diatomic:
  - gas, 112, 113
  - linear chain, 52, 53
    - acoustic mode, 53
    - optical mode, 53
  - molecule, 55
- dielectric constant, 143
  - complex, 196, 198, 199
  - dispersion, 196
  - free space, 147
  - frequency dependence, 345
  - high, 195
  - imaginary, 196, 198, 199
  - real, 196, 198, 199, 207

- differential:
  - equation:
    - associated Legendre, 440
    - Bessel, 440, 449
    - Chapter 28, 437
    - characteristics, table, 440–443
    - first order, 438
    - Helmholtz, 447, 449
    - Hermite, 440
    - Laguerre, 440
    - Laplace, 447
    - Legendre, 440, 457
    - second order, 439
    - self adjoint, 439
  - exact, 102
  - inexact, 102
  - operator, 403, 405, 406
- diffraction, 212, 213
  - Fraunhofer, 213, 216, 218
  - Fresnel, 213
  - multiple slits, 214
  - slit, 215
- diffusion, 326
- digamma function, 465
- diopter, 208
- dipole:
  - electric, 161, 162
    - induced, 320
    - fields, 164
    - matrix element, 175
    - selection rules, 175
  - magnetic, 166
    - force, 167
    - interaction, 167
    - selection rules, 175
    - torque, 167
  - moment of molecule, 57
- Dirac spin orbit correction, 296
- direct:
  - integral, 305
  - product, 387
    - matrix, 258–260
    - sum, 387
- direct product, 474
- direction cosine, 34, 35
- Dirichlet boundary conditions, 153, 154
- dispersion:
  - anomalous, 207
  - normal, 207
  - relation, 51
- dissipation function, Rayleigh, 5
- distribution:
  - Bose-Einstein (BE), 137
  - Fermi-Dirac (FD), 114, 137
  - functions, Chapter 9, 123
  - Maxwell, 133, 134, 136
  - Maxwell-Boltzmann, 137
  - Planck, 139
  - velocity, 124
- divergence theorem, 402
- donor, 359
- doping:
  - electron, 358
  - hole, 359
  - semiconductor, 358
- Doppler shift, 95
- dot product, 414
- double factorial, 467
- down quark, 385
- Drude model for conductivity, 342
- dual field strength tensor, 179, 182
- Dulong and Petit law, 114, 115
- dynamics, non-linear, 68
- eccentricity, 17
- eightfold way, 434
- Einstein velocity addition law, 91
- Einstein-Nernst relation, 326
- electric:
  - dipole, 161, 162
    - radiation, 223
  - field, 143
    - integral expression, 152
    - source, 148
  - hexadecapole, 161
  - monopole, 162
  - multipole, 161
  - octapole, 161
  - quadrupole, 161, 162
- electrodynamics, relativistic, Chapter 12, 176
- electromagnetic:
  - field tensor, 177
  - force, 364
  - interaction strength, 382
  - momentum, 190
- electron:
  - capture, 374
  - classical radius, 239, 241

- delocalization, 342, 357, 358
- diffraction, 334
- doping, 358
- elastic scattering, 381
  - force, 364
  - hopping, 338
  - transport, 342
- electron spin resonance, 261, 262
- electrophoresis, 325
- electrostatics, 143, 151
  - Chapter 10, 142, 143
- elementary particles, Chapter 26, 379
- ellipse:
  - aphelion, 17
  - focus, 17
  - perihelion, 17
  - semi major axis, 17
  - semi minor axis, 17
- ellipsoid:
  - magnetization, 170–174
  - nucleus, 367
  - oblate, 367
  - polarization, 170–174
  - prolate, 367
- elliptic orbit, 16, 17
  - apogee, 17
  - perigee, 17
- enantiomorphic, 434
- energy:
  - band, 341
    - binding energy, 367
    - two dimensions, 354
    - two dimensions free electron, 358
  - binding of nucleus, 367
  - center of gravity, 248
  - charge distribution, 165
  - density:
    - electric, 145, 146
    - magnetic, 145, 146
  - free, 107, 108, 111
  - gap:
    - free electron, 351
    - semiconductor, 360
  - internal, 107, 122
  - surface, 368
- ensemble, 125
  - canonical, 125, 126
  - grand canonical, 127
  - microcanonical, 125
- entangled state, 476, 481, 489
- entanglement, 471, 479
- enthalpy, 107, 108
- entropy, 104
  - change, 111
  - density, 116
  - paramagnetism, 133
  - spin, 132
  - statistical definition, 132
  - transport, 119
- equipartition theorem, 130, 324
- error integral, 464
- Ettinghausen:
  - coefficient, 120
  - effect, 117, 119, 120
- Euclidean Algorithm, 484
- Euler:
  - angles, 30
  - parameter, 410
  - three-body problem, 26
- Euler-Mascheroni constant, 416, 464
- exact differential, 102
  - entropy, 104
- exchange integral, 305
- exciton, 169
  - energy, 337
  - Frenkel exciton, 338
  - Mott-Wannier, 337, 338
  - radius, 337
- expectation value of operator, 265
- face centered cubic, 329
- Faraday law, 159
- Fe, 367, 369, 376
- Feigenbaum:
  - diagram, 75–77, 79, 80
  - limit, 79
  - number, 79
  - Rössler, 84, 85
- Fermi:
  - energy, 115, 348
  - gas, 343
  - surface, 347
    - spherical, 349
  - temperature, 115, 120, 347
- Fermi-Dirac (FD):
  - distribution, 137
    - function, 114, 347
  - statistics, 136, 343, 347

- fermion, 380
- ferrocene, 434
- Feynman diagram, 381
- field:
  - electric, 143
  - magnetic, 143
- field strength tensor, 177–179
  - dual, 179, 182
- fine structure constant, 293, 383
- fission, 367
- fluctuation:
  - force, 324
  - liquid, 323
- fluids, Chapter 23, 319
- forbidden by strong interaction, 393
- force, 382
  - central, 12
  - centrifugal, 37, 325
  - collinear, 11
  - Coriolis, 37, 38
  - Coulomb, 364, 380
  - electromagnetic, 364
  - four-vector, 96
  - fundamental, 364, 380
    - characteristics, 383
  - gravity, 364
  - harmonic, 20
  - Hooke's law, 20
  - inverse square, 16, 20, 21
  - Lorentz, 11, 143
  - mediator, 383
  - not collinear, 11
  - power law, 21
  - source, 383
  - strength, 380
    - relative, 364, 365, 383
  - strong, 364
  - time constant, 383
  - van der Waals, 320
  - weak, 364
- four-vector, 90
  - examples, 93
  - force, 96
  - light-like, 92, 93
  - space-like, 92, 93
  - time-like, 92, 93
- Fourier:
  - law, 116
  - pulse decomposition, 229
  - series, 416, 418, 419
  - transform, 418, 419, 487
- Fraunhofer diffraction, 213, 216, 218
- Fredholm equation, 423
- free:
  - electron:
    - approximation, 342
    - specific heat, 115
  - energy:
    - Gibbs, 107, 108, 111
    - Helmholtz, 107, 108, 111, 122
- Frenkel exciton, 338
- frequency:
  - domain, 421, 422
  - modulated (FM), 202
  - Fresnel diffraction, 213
- friction, 2
  - coefficient, 324, 325
- Frobenius' method, 444
- fusion, nuclear, 378
- g-factor, free electron, 168
- Ga, 359
- Galilean transformation, 88, 89
- gamma:
  - function, 462
    - complete, 464
    - Euler formula, 464
    - figure, 466
    - incomplete, 464
    - table of values, 465
    - Weierstrass definition, 464
  - ray emission, 374, 376
    - recoilless, 376
- gap of energy in semiconductor, 360
- gas, 320
  - Fermi, 343
  - law:
    - adiabatic, 113, 114
    - ideal, 112, 320
  - van der Waals, 321
- gauge:
  - Coulomb, 183
  - London, 183
  - Lorentz, 183
  - transformation, 183
- Gauss' law, 149
- Ge, 337, 358, 359

- Gegenbauer polynomial, generating function, 457
- Gell-Mann, Nishijima formula, 384, 385
- Gibbs:
- free energy, 107, 108, 111
  - phase rule, 109, 110
  - phenomenon, 417
- gluon, 382, 383
- gradient:
- concentration, 326
  - operator, 244
- Gram-Schmidt procedure, 445
- grand:
- canonical ensemble, 127
  - potential, 128
- graviton, 382, 383
- gravity:
- force, 364
  - interaction, 382
- greatest common divisor, 483
- greatest common divisor, 484
- Green:
- function, 154, 469
  - properties, 470
  - theorem, 402
- group:
- abelian, 430
  - cyclic, 430
  - multiplication table, 430
  - point, 432, 433, 435
  - representation, 431
  - semidirect product, 434
  - space, 434
  - theory, 430
    - hadron classification, 387
    - velocity, 204
- guide wavelength, 200
- guided waves, 200
- gyromagnetic ratio, 130
- Hadamard transformation, 477
- hadron, 380
  - classification by mass, 389
- half life of radioactive decay, 373
- Hall, 117
  - angle, thermal, 121
  - coefficient, 361
  - effect, 121, 360–362
- Hamilton:
- characteristic function, 63
  - equation, 60
  - principal function, 63
  - principle, 4
- Hamilton-Jacobi equation, 62
- Hamilton-Jacobi equation, 62
  - harmonic oscillator, 63
- Hamiltonian:
- charge in electromagnetic field, 7
  - electromagnetic, 184
  - formulation, Chapter 1, 1, 6
  - harmonic oscillator, 7, 61
  - integrable, 69
  - Kepler problem, 7
  - matrix, 263
  - non-integrable, 69
  - perturbation, 69
  - rotation, 55, 56
  - symmetric top, 8, 55
  - vibration, 57
- Hankel:
- function, 452
  - transform, 422
- harmonic:
- motion, 20
  - oscillator, 21
    - action-angle variable, 65
    - canonical transformation, 61
    - Hamilton-Jacobi equation, 63
    - Hamiltonian, 61
    - Henon-Heiles Hamiltonian, 81
    - Langrangian, 3
    - $N$ -tori, 71, 72
    - orbital states, 272, 273
    - pair of, 71, 72,
    - partition function, 130
    - phase space, 62, 70
    - square well, 266
    - three-dimensional, 266, 270, 271, 273
    - series, 416
- Hartree-Fock:
- equations, 305
  - method, 305
- He, 369
  - catalyst, 378
  - fusion, 378
  - nucleus, 367
- heading, 31

- heat:
  - energy flow, 116
  - engine efficiency, 105
  - transport, 346
- helicity, 375
- neutrino, 376
- helium:
  - Schrödinger equation, 297, 298
  - singlet and triplet states, 298
  - variational method, 299
- Helmholtz:
  - equation, 447, 449
  - free energy, 107, 108, 111, 128
- Henon-Heiles:
  - energy surface, 82
  - Hamiltonian, 81
- Hermite:
  - equation, 440
  - polynomial, 272, 446
- hermitian matrix, 409, 412
- hexadecapole, electric, 161
- hexagonal, 327–329
  - close packed, 328
- Hilbert space, 473
- hole:
  - delocalized, 357, 358
  - doping, 359
- holonomic constraint, 4, 5
- Hooke's Law, 20
- hopping electron, 338
- Huygens:
  - principle, 213
  - wavelet, 214
- hydrogen:
  - atom, 291, 292
  - electron density, 294
  - energy, 292, 293
  - expectation values, 294
  - ortho, 141
  - para, 141
  - Schrödinger equation, 291, 292
  - spin orbit correction, 295
  - Zeeman effect, 310
- hyperbola:
  - equation, 18
  - figure, 19
  - nearest approach, 18
- hyperbolic:
  - motion, 185
- orbit, 16
- ideal gas:
  - law, 320, 322
  - specific heat, 112
- ignorable coordinates, 8
- impact parameter, 22, 23, 235–238
- impedance, characteristic:
  - free space, 146, 190, 200
  - unbounded medium, 201
  - waveguide, 201
- In, 359
- independent electron approximation, 342
- index of refraction, 147, 190
  - optical, 207
- inertial system, 37
- inexact differential, 102
- infinite series, 415
- infrared active mode, 57
- insulator, 344
- integral:
  - equation, 421
  - transform, 421
- interaction:
  - coupling strength, 381
  - electromagnetic, 383
  - gravity, 383
  - strong, 383
  - weak, 383
- interference, 212, 213
  - slits, 215
- interferometer of Michelson, 215
- internal energy, 107
- invariant, 493
  - adiabatic, 186
  - PCT, 100
  - tensor, 179, 180
- inversion, 434
  - space, 99
  - space-time, 99
  - time, 99
- ion traps, 489
- ionic radii, 301
  - table, 303
- ionization:
  - energy, 304
  - potential, 302
- irreducible:
  - representation, 431

- tensor, 252
  - commutation rules, 254
  - quadrupole, 252
- irrotational vector, 146
- isochoric, 111
- isospin, 383, 385
- isotope, 365
  - stable, 371, 489
  - unstable, 371
- isotopic enrichment, 489
- jj* coupling, 247
- KAM:
  - curve, 72
  - surface, 72
  - theorem, 72
- K-capture, 374
- KdeV equation, 203, 204
- Kepler problem, 10, 19
  - conjugate momenta, 6
  - Lagrangian, 3
  - second law, 14
- kernel, 422
- Kevin-Planck statement, 104
- kinetic energy, 3
  - rotational, 38
  - translational, 38
- Klein-Gordon equation, 204, 205
- Kolmogorov-Arnold-Moser (KAM) theorem, 72
- K-particle, 389
- Kramers-Kronig, 196
- K-shell of atom, 292, 305, 341
- k*-space, rectangular lattice, 355
- ladder operator, 246
- Lagrange:
  - equation, 4, 5
  - multiplier, 5
  - three body problem, 26
- Lagrangian, 3
  - definition, 3
  - electromagnetic, 184
  - formulation, Chapter I, 1
  - harmonic oscillator, 3
  - Kepler problem, 3
  - symmetric top, 3, 41
- Laguerre:
  - equation, 292, 440
  - polynomial, 267, 292, 446
- Langevin equation, 324
- Laplace:
  - equation, 153, 426, 447, 448
  - transform, 422, 423
  - table, 424
- Laplacian, 245, 266
  - spherical coordinates, 245, 291
- Larmor radiation formula, 227, 239
- laser, 121
- latent heat, 111
- lattice:
  - direct, 331
  - polarization, 337
  - reciprocal, 331
  - two-dimensional oblique, 334
  - vibration, 336
- Laurent series, 427
- Legendre:
  - associated:
    - equation, 440, 458
    - polynomial, 446, 458
  - duplication formula, 467
  - equation, 440, 457
  - generating function, 458
  - orthogonality, 458
  - polynomial, 318, 446, 457
- lens, 207, 208
  - convergent, 207, 208
  - divergent, 208, 209
  - focal point, 207
  - formula, 207, 208
  - magnification, 208
  - maker's formula, 208
- Lenz' law, 159
- lepton, 380, 382
  - stability, 395
- Levi-Civita symbol, 66, 67, 246
- Li, 369
- Lie algebra, 434
- light velocity, 146
- linear:
  - chain of atoms, 48, 50
    - Brillouin zone, 52
    - normal mode, 50
    - travelling wave, 50
  - vibration, 48

- momentum, 243, 244
  - commutator, 245
- liquid:
  - drop nuclear model, 368
  - state, 323
- logistic equation, 74–76
  - chaos, 74
- Lorentz:
  - condition, 97, 183
  - contraction, 94
  - force, 2, 11, 143, 183
  - gauge, 183
  - transformation, 89, 90, 376
    - general, 98
- Lorentzian line shape, 197, 421
- Lorenz:
  - attractor, 86
  - equations, 85
  - number, 121, 347
- L-shell of atom, 292, 305, 341
- magic number:
  - atom, 299
  - nucleus, 369, 371
- magnetic:
  - dipole:
    - moment, current loop, 167
    - radiation, 223
  - field, 143
    - around wire, 150, 157, 158
    - source, 150
  - flux, quantized, 338
  - moment:
    - definition, 167
    - nucleus, 175
    - angular momentum, 168
  - magnetization, 144
    - calculation, 132
    - ellipsoid, 170–174
    - from current density, 167
    - magnetic dipole distribution, 168
  - magnetogyric ratio, 130
  - magnetoresistance, 117
  - magnetostatics, 143, 156
    - wire, 156
      - Chapter 10, 142
- maser, 121
- mass, effective, 169
- mathematical physics:
  - Chapter 27, 399
  - Chapter 28, 437
- matrices, 408
  - Chapter 27, 399
- matrix:
  - addition, 408
  - angular momentum, 256–258
  - direct product, 258–260
  - Hamiltonian, 263
  - hermitian, 409
  - inverse, 408
  - orthogonal, 32, 410
  - Pauli, 36, 256, 412
  - rotation, 32
  - transpose, 408
  - unitary, 261, 409
- Matthiessen rule, 346
- Maxwell:
  - distribution, 133, 134, 136
  - equations, 144
    - homogeneous, 181
    - inhomogeneous, 181
    - relativistic, 180
  - relations, 108
- Maxwell-Boltzmann:
  - distribution, 137
  - statistics, 342
- mean field theory, 111
- media, Chapter 11, 160
- medium, conducting, 197
- Mellin transform, 422
- melting, 111
  - line, 322, 323
- meson, 380, 383
  - angular momentum, 389
- octet:
  - plus singlet, 387
  - table of characteristics, 388
- parity, 389
- pseudoscalar, 389
  - octet, 387, 388
  - quark-antiquark pair, 387
- metric tensor, 177
- Michelson interferometer, 215
- Michelson-Morley experiment, 88–90
- microcanonical ensemble, 125
- microwave region, 56
- Miller index, 332

- Minkowski space, 89, 90, 99
- mirror:
  - focal point, 209
  - formula, 210
  - magnification, 210
  - spherical, 209
- Mn, 299
- mobility, 326
  - definition, 325
- modulated wave, 201
- modulation, 203
- molecule:
  - dipole moment, 57
  - triatomic, 46
- moment of inertia, 38, 244
  - parallel axis theorem, 39
  - principal, 39
  - several solids, 40
  - table, 40
- momentum:
  - angular, 13, 243, 244
  - canonical, 14, 60
  - conjugate, 5, 184, 243
  - electromagnetic, 190
  - linear, 11, 243, 244
  - operator, 244
  - space, 420
- monatomic gas, 112, 113
- monoclinic, 327–329
- monopole, electric, 162
- Mosley's law, 304, 305
- Mossbauer:
  - effect, 376
  - transition, 377
- motion, non-periodic, 21
- Mott-Wannier exciton, 337
- multipole:
  - atomic, 175
  - Chapter 11, 160
  - electric, 161
    - force, 166
  - moment, 161
    - generation, 163
  - nuclear, 175
- muon decay, 395
- N*-tori, 71, 72
- n-type semiconductor, 346, 359
- Na, 301, 341
- NbTi, 338
- negative temperature, 121
- Nernst:
  - coefficient, 120
  - effect, 117, 118, 120
- Neumann:
  - boundary conditions, 153, 154
  - function, 445, 452
- neutrino helicity, 376
- neutron:
  - diffraction, 334
  - energy level scheme, 371
  - force, 364
  - instability, 374
  - lifetime, 373
  - radius, 366
  - star, 366
- Newton rings, 215
- Newton's law, 2
  - covariant form, 96
  - first, 11
  - gravitation, 12, 38
- Newtonian mechanics, 88
- Ni, 374, 376
- nitrogen, 377
- NMR, 489
- non-inertial system, 37
- non-linear dynamics, 68
  - chaos, 68
- nonet, 387
- normal mode, 45
  - secular equation, 46
- Np, 374
- nuclear:
  - fusion, 378
  - magnetic resonance, 261, 262, 422, 489
- nuclei, Chapter 25, 363
- nucleon:
  - isospin, 383
  - radius, 366
- nucleus:
  - daughter, 373
  - ellipsoid, 367
  - radius, 238
  - size, 366
  - stable, 367
- nutaton, 41
- oblate ellipsoid, 367

- oblique:
  - incidence, 193
  - two-dimensional lattice, 334
- OCS, 48
- octapole, electric, 161
- Ohm's law, 198, 199, 344
- omega particle ( $S_2^-$ ) decay, 394
- one-dimensional quantum systems, Chapter 20, 275
- operator:
  - angular momentum, 244
  - expectation value, 265
  - gradient, 244
  - ladder, 246
  - Laplacian, 266
  - momentum, 244
  - raising and lowering, 246, 258
  - time dependent, 265
  - total angular momentum, 245
- optical path, 191
- optics, Chapter 14, 206
- orbit:
  - bounded, 19–21
  - circular, 17
  - closed, 19, 20
  - commensurate, 20
  - conic section, 16
  - elliptic, 16, 17
  - hyperbolic, 16, 22, 23
  - incommensurate, 20, 21
  - open, 21, 22, 23
  - parabolic, 16
  - perturbed, 72
- orbital:
  - angular momentum, 246
  - quantum number, nucleus, 369
- order:
  - long range, 323
  - short range, 323
- ortho-para statistics, 140, 141
- orthogonal functions, Chapter 28, 437
- orthogonality, 445
- orthohydrogen, 141
- orthorhombic, 327–329
- oscillation:
  - Chapter 4, 42
  - longitudinal, 49
  - transverse, 53, 54
- oscillator:
  - harmonic, 21
  - strength, 197
- oxygen nucleus, 369
- p-type semiconductor, 346, 359
- packing fraction, 328
- parabolic orbit, 16
- parahydrogen, 141
- parallel axis theorem, 39
- paramagnetism, 130
  - entropy, 133
- parity, 34, 35, 293, 445
  - antiquark, 389
  - baryon, 391
  - harmonic oscillator, 274
  - meson, 389
  - non-conservation, 375
  - operation, 100
  - quark, 389
  - square well, 286
- particle:
  - distinguishable, 124
  - indistinguishable, 124
  - virtual, 381
- partition function, 121, 122, 126
  - harmonic oscillator, 130
  - spin  $\frac{1}{2}$  in magnetic field, 131
- past and future, 91
- Pauli:
  - exclusion principle, 368
  - spin matrix, 256, 412
    - anticommutation, 36
    - definition, 36
    - rotation, 36
- Pb, 369, 374
  - nucleus, 371
- Peltier, 118, 120
  - coefficient, 120
  - effect, 117
- periclase, 331
- perigee, 17
- perihelion, 17
- periodic table, 301, 305
- permeability, 143
  - free space, 147
- permittivity, 143
- permutation, 66
  - cyclic and anticyclic, 66

- symbol, 66
- perturbation:
  - chaos, 69
  - degenerate, 312
  - first order, 308
  - Hamiltonian, 69
  - hydrogen Zeeman effect, 309–311
  - second order, 308
  - theory, Chapter 22, 306
  - time:
    - dependent, 313, 315
    - independent, 308
  - wave function, 309
- perturbed orbit, 72
- phase:
  - change, 111
  - rule, Gibbs, 109, 110
  - shift, scattering, 318
  - space, 60, 61
    - circle, 71
    - ellipse, 71
    - harmonic oscillator, 62, 70
    - normalized coordinates, 71
  - transition, 111, 322
    - line, 110
  - velocity, 204
- phonon, 336
  - acoustic, 336, 337
  - density of states, 114
  - longitudinal, 336, 337
  - optical, 336, 337
  - transverse, 336, 337
- phosphorus, 358
- photon, 380
  - mediator, 383
  - statistics, 138, 139
- pion:
  - decay, 394
  - isospin, 383
  - lifetime, 94
- pitch, 31
- Planck distribution, 139
- plane wave, 189
- plasma, 198, 337
  - definition, 199
  - frequency, 199, 337, 345
  - wavelength, 199
- plasmon, 337
- Poincaré:
  - map, 81, 82
  - transformation, 98
- point group, 432, 433, 435
- Poisson:
  - bracket, 66
    - angular momentum, 66
  - equation of motion, 66
  - equation, 153, 154
- polariton, 337
- polarizability, 58, 195
- polarization, 144
  - circular, 211, 212
  - electric dipole distribution, 168
  - ellipsoid, 170–174
  - elliptic, 211
  - lattice, 337
  - light, 210
  - linear, 195, 211, 212
- polaron, 337
- polynomial:
  - associated Legendre, 446, 459
  - Chebyshev, 446, 457
  - Gegenbauer, 457
  - Hermite, 272, 446
  - Laguerre, 267, 294, 446
  - Legendre, 444, 457
  - table, 446
  - ultraspherical, 457
- positron, decay, 374
- potential:
  - Coulomb, 267
    - barrier, 281, 282
  - chemical, 128
  - energy, 3
    - effective, 15
  - grand, 128
  - ionization, 302
  - one-dimensional, 276
  - periodic, 351
  - power law, 21
  - scalar, 146, 152
  - step, 278, 279
  - vector, 145
- power series, 307
- Poynting vector, 146, 190
- precession, 41
- prefactor, 326
- prime factors, 482

- prime numbers, 482
- prolate ellipsoid, 367
- propagation constant, 196, 280
- proton, 366
  - cycle, 378
  - energy level scheme, 371
  - force, 364
  - from sun, 377
  - stability, 374
- pseudoscalar, 34, 35
  - meson, 389
- pseudotensor, 34, 35
- pseudovector, 34, 35, 413
  
- Q-value, 24
- QCD, quantum chromodynamics, 382
- quadratic iterator, 74
- quadrupole:
  - electric, 161, 162
  - irreducible tensor form, 252
  - longitudinal, 163, 164
  - tensor, 162
    - operator, 252
    - transverse, 163, 164
- quantum chromodynamics, 382, 395
- quantum computer, 472, 482, 489
- quantum Fourier transform, 487
- quantum number:
  - baryon, 384
  - hydrogen atom, 292
  - principal, 292
  - orbital, 292
  - vibration, 57
- quark, 365, 380, 382
  - bottom, b, 398
  - charge, 385
  - charm, c, 387
  - color, 383, 395
  - parity, 389
  - strong charge, 395
  - table of characteristics, 386
  - top, t, 398
    - up, down, strange, u, d, s, 385
- quasistatic, 102
- qubits, 472
  
- Racah  $V$  coefficient, 251
- radiation:
  - accelerated charge, 226
    - Chapter 15, 219
    - charge density, 220
    - Cherenkov, 230–232
    - current density, 220
    - electric dipole, 222, 223
    - far zone, 221, 222
    - Larmor, 239
    - magnetic dipole, 223
    - quasi stationary, 221
    - relativistically accelerated charge, 227
    - spherical harmonics, 221
    - tesseral harmonics, 221
    - transition, 231, 232
    - zones, 221
  - radii, 302, 303
  - radioactive, 366
    - decay, 371, 372
      - of uranium, 375
      - half life, 373
      - mean lifetime, 373
    - series, 374
  - Raman active mode, 57
  - rapidity, 90
  - Rayleigh dissipation function, 5
  - reflection, 191
  - refraction, 191, 192
  - relativistic electrodynamics, Chapter 12, 176
  - relativity, 87
  - relaxation:
    - time, 327, 343
    - approximation, 342
  - representation:
    - group, 431
    - irreducible, 431
  - residue theorem, 426, 427
  - resistivity, 117, 344, 345
    - Bloch law, 346
  - resonance:
    - electron spin, 261, 262
    - nuclear magnetic, 261, 262
  - Riemann zeta function, 464
  - Righi-Leduc:
    - coefficient, 121
    - effect, 117, 119, 120
  - rigid body, 28
    - center of mass, 29
    - Chapter 3, 28
    - definition, 29
    - not so rigid, 44

- rotation, 38
- vibration, 43
- rod depolarization factor, 170
- Rodriguez formula, 457
- roll, 31
- Rössler:
  - attractor, 83
  - equations, 83
  - Feigenbaum diagram, 84, 85
- rotation:
  - coordinate system, 36
  - determinant, 33
  - direction cosine, 34, 35
  - energy, 56
  - Euler angles, 30
  - Hamiltonian, 56
  - matrix, 32
  - rigid body, 38
  - Schrödinger equation, 56
  - space-time, 89
  - two-dimensional representation, 35
  - xyz convention, 30
- rotational Hamiltonian, 55
- Russell Saunders coupling, 247
- Rutherford:
  - cross section, 23
  - scattering, 23, 24, 239
- Rydberg formula, 292
- Sb, 358
- scalar, 34, 35, 413
  - product, 414
- scattering, 22, 23, 317, 318
  - angle, 23, 237, 238
  - cross section, 22, 23, 238, 241
  - inelastic, 24
  - Rutherford, 24, 239
  - Thomson, 240, 241
- Schrodinger equation:
  - Chapter 19, 264
  - conduction electrons, 350
  - helium atom, 296, 297
  - hydrogen atom, 267, 291, 292
  - one-dimensional, 276
  - potential step, 279
  - rotation, 56
  - separable, 266
  - spherical coordinates, 266
- time:
  - dependent, 313–315
  - independent, 265
- Se, 299
- secret codes, 482
- secular equation, 411
- Seebeck:
  - coefficient, 116
  - effect, 116–118
- self:
  - adjoint, 439
  - diffusion, 326
  - energy, Coulomb, 239
- semiconductor, 344, 357
  - doped, 341, 358
  - intrinsic, 357
  - n-type, 346, 359
  - p-type, 346, 359
- semidirect product group, 434
- semiempirical binding energy formula, 368
- series, 415
  - Fourier, 416, 418, 419
  - harmonic, 416
  - infinite, 415
  - Laurent, 427
- shell model, 370
  - nuclear energy level scheme, 372
  - nucleus, 369
- Si, 337, 358, 359
- similarity transformation, 34, 35, 177, 410, 412, 431
- sine transform, 419
- sine-Gordon equation:
  - antikink solution, 205
  - kink solution, 205
- slab depolarization factor, 171
- slit:
  - double, 215, 217
  - multiple, 214, 215
  - single, 215
  - wide, 217
- Snell's law, 194
- solenoidal vector, 145
- solids, Chapter 23, 319
- solitary wave, 202–204
- soliton, 202–204
- space:
  - group, 434
  - lattice, 329

- like, 92, 93
- special unitary group  $SU(n)$ , 387
- specific heat:
  - conduction electrons, 115
  - Debye, 54, 114, 130
  - free electron, 115
  - ideal gas, 112
  - integral, 105
  - ratio, 113
  - solid, 114
- spectroscopy:
  - infrared, 57
  - notation, 274
  - Raman, 572
  - vibration, 57, 58
- spherical harmonic, 246, 459
  - addition theorem, 462
  - definition, 155, 459
  - orthogonality, 461
  - potential problem, 154
  - table, 460
- spherical polar coordinates, 405, 406
- spin:
  - angular momentum, 246
  - nucleus, 369
- spin orbit:
  - coupling constant, 371
  - energy splitting for hydrogen, 296
  - interaction, 248
    - Dirac correction, 296
    - hydrogen, 296
    - nuclear, 371
  - splitting, 371
- spinor, 331
- spinor, 412
- square well:
  - infinite, 269, 270
  - one-dimensional, 283–289
  - parity, 286
  - three-dimensional, 267, 268
- stability line, 371
- standing wave, 189, 277
- statistical mechanics, 123, 124
  - accessible states, 124
  - Chapter 9, 123
  - ensemble, 125
  - equal apriori probability, 124
  - relation to thermodynamics, 121, 122, 129
- statistics:
  - Bose-Einstein (BE), 136, 138, 139
  - classical, 134–136
  - Fermi-Dirac (FD), 136, 343, 347
  - Maxwell-Boltzmann (MB), 342
  - nuclear 141
  - ortho-para, 140, 141
  - photon, 138, 139
  - quantum, 134–136
- Stefan-Boltzmann:
  - constant, 140
  - law, 139
- Stern-Gerlach experiment, 168
- Stirling series, 465
- Stokes, 2
  - law, 325
  - theorem, 402
- strange quark,  $s$ , 385
- strangeness,  $S$ , 384
  - conservation, 393
  - law, 384
  - nonconservation, 393
  - interactions, 394
- streamline flow, 2, 73
- strong:
  - force, 364
  - interaction, forbidden, 393
- $SU(2)$  group, decomposition, 398
- $SU(3)$  group, 387, 390, 434
- $SU(4)$  group, 396
  - decomposition, 396
  - supermultiplets, 397
- subgroup, 431
- sublimation, 322, 323
- superconductivity, 338
- superposition of states, 481
- susceptibility:
  - electric, 169
  - magnetic, 169
- symmetric:
  - stretch vibration mode, 48, 49
  - top, 6, 39
    - canonical momenta, 41
    - Hamiltonian, 8, 55
    - Lagrangian, 3, 41
    - molecule, 55
- tau particle,  $\tau$ , 395

- temperature:
  - Fermi, 115, 120, 347
  - fixed, 125
  - negative, 121
- tensor, 413
  - alternating, 67
  - Chapter 27, 399
  - contraction, 179
  - contravariant, 177, 415
  - covariant, 177, 415
  - invariant, 179, 180
  - irreducible, 251
  - isotropic of rank 3, 67
  - metric, 177
  - mixed, 415
  - rank, 34, 35
  - spherical, 251
  - transformation, 33
- terminal speed, 325
- Tesseral harmonic:
  - definition, 155
  - potential problem, 154
  - table, 463
  - tabulation, 156
- tetragonal, 327–329
- Th, 374
- thermal:
  - conductivity, 117, 346
  - current, 116
  - energy, 112
  - equilibrium, 342
- thermodynamics, 101, 102
  - Chapter 8, 101
  - first law, 103, 105, 108, 112
  - four laws, 103
  - relation to statistical mechanics, 129
  - second law, 104, 105
  - third law, 104
  - zeroth law, 104
- thermoelectric:
  - coefficient, 116
  - effects, 116, 117
- thermomagnetic effects, 116, 117
- thermopower, 116
- Thomson:
  - relation, 120
  - scattering, 240, 241
- three:
  - body problem, 24–27
  - Euler, 26
  - Lagrange, 26
  - restricted, 25
  - quark model, 385
- time:
  - constant for particle decay, 382
  - domain, 421, 422
  - dilatation, 94
  - like, 92, 93
  - reversal, 100
- top quark,  $t$ , 398
- torque, 244
  - charge distribution, 165
- trace, 413
- transcendental equation, 286, 287
- transform:
  - Fourier, 418, 419
  - Hankel, 422
  - integral, 421
  - Laplace, 422, 423
  - Mellin, 422
- transformation:
  - boost, 178
  - Galilean, 88, 89
  - gauge, 183
  - improper, 99
  - Lorentz, 89, 90, 98, 178, 376
    - general, 177
  - Poincaré, 98
  - proper, 99
  - similarity, 34, 35, 177, 410, 412, 431
  - vector, 33
- transition:
  - electric:
    - dipole, 175
    - quadrupole, 175
  - magnetic dipole, 175
  - Mössbauer, 377
  - phase, 322
  - probability, 316
    - figure, 317
    - per unit time, 316
  - radiation, 231, 232
- transmission coefficient, 192
- transport:
  - electron, 342
  - entropy, 119
  - entropy density, 116

- heat, 346
- transverse:
  - electric (TE) wave, 200
  - electromagnetic (TEM) wave, 200
  - magnetic (TM) wave, 200
- traveling wave, 189, 277
- triatomic molecule, normal mode, 46
- triclinic, 327–329
- trigonal, 327–329
- triple point, 110, 322, 323
- truth quark, t, 395, 398
- tumbling liquid, 323
- turbulence, 2, 73
  
- ultraspherical polynomial, 457
- ultraviolet region, 199
- uncertainty condition, 419, 420
- unit cell:
  - body centered, 327, 328
  - cubic, 330
  - face centered, 328
  - primitive, 327, 328, 334
  - top and bottom centered, 328
- unitary matrix, 261, 409, 410
- unitary transformations, 473
- up quark, u, 385
  
- van der Waals:
  - constants, 322
  - equation, 110, 320, 322
  - force, 320
  - gas, 321
- vaporization, 111
- variational:
  - method for helium, 298
  - principle, 8
- vector, 34, 35, 413
  - axial, 34, 35
  - irreducible tensor form, 252
  - irrotational, 146
  - relations, 400, 401
  - solenoidal, 145
  - transformation, 33
- velocity:
  - boost, 98
  - conduction electron, 353
  - distribution, 124
  - group, 204
  - light, 146, 200
  
- phase, 204
- wave, 190
- vibration:
  - asymmetric stretch, 57
  - Chapter 4, 42
  - lattice, 336
  - mode, 43
  - molecular, 43
  - normal mode, 43, 45, 114
  - quantum number, 57
  - spectroscopy, 58
  - symmetric stretch, 57
- virial, 20
  - of Clausius, 20
  - theorem, 20
- virtual:
  - particle, 381
  - photon, 381
  - work, 9
- Volterra equation, 425
- vortex, 339
  
- W-particle,  $W^\pm$ , 382, 383
- Walsh-Hadamard transformation, 477, 486
- wave, 202
  - amplitude modulated (AM), 201
  - carrier signal, 202
  - equation, 183
  - frequency modulated (FM), 202
  - guided, 200
  - modulation signal, 202
  - partial, 318
  - plane, 189
  - propagation, 188
  - scattered, 318
  - solitary, 202–204
  - standing, 189, 277
  - transverse:
    - electric (TE), 200
    - electromagnetic (TEM), 200
    - magnetic (TM), 200
  - traveling, 189, 277
- wave function:
  - angular momentum, 249
  - antisymmetry, 298
  - helium atom, 298
  - hydrogen atom, 292
  - radial, 294
- wave propagation, Chapter 13, 188

- wavelength:
  - Compton, 204
  - cutoff, 200
- weak force, 364, 382, 383
- weighting function, 445
- Weizsäcker formula, 368
- Wiedermann-Franz law, 116, 121, 347
- Wien law, 139, 140
- Wigner 3- $j$  symbol, 251
- Wigner-Seitz cell, 334–336
- wire in magnetic field, 157, 158
- Wronskian, 445
- Wyckoff crystal structures, 330
- x-ray:
  - beam, 333
  - diffraction, 334
- yaw, 31
- Young:
  - experiment, 215, 216
  - modulus, 44
- Z-particle,  $Z_0$ , 382, 383
- Zeeman effect, 167, 184
  - hydrogen, 259, 310
- Zustandsumma, 126