

Index

- C_g , 121
- C_q , 133
- M_{56} , T_{566} , U_{5666} , 163, 169
- β -function (see Twiss), 27
- $\mathcal{D}$, 128
- $\mathcal{H}$, 135, 136, 137, 139
- Accelerator driven reactor, 10
- Action-angle
 - co-ordinates, 50
 - beam–beam dimensionless, 174
 - detuning, 109
 - distribution, 52, 55, 61
- Adiabatic damping (see Damping), 58
- Algorithm
 - matrix inversion, 6
 - Newton search, 5
 - square root, 6
- Antiproton, 7, 71
- Aperture
 - dynamic, 103–105
 - physical, 103
- Beam position monitor, 87, 187
- Beam size
 - bunch length, 15, 60, 62, 134, 160
 - distribution moments, 53, 56
 - flat, 53
 - momentum spread, 60, 62, 95
 - round, 53
 - total horizontal, 54
 - transverse, 53, 59
- Beam–beam
 - cf space charge, 172, 180
 - detuning and resonance functions, 174, 182
 - effect, 10, 139, 180
 - interaction, 107, 170, 172, 185, 190
 - single round, 170
 - parameter ξ , 170, 172, 180, 183
 - horizontal and vertical, 173
 - simulation, 180, 190
 - tune shift, 173
- Bessel function, 77, 185
 - identity, 78
 - modified, 118, 174
 - roots, 77
- Betatron, 3, 81
 - off-momentum motion, 94
 - oscillation, 13, 126
 - envelope, 52
- Biot–Savart law, 70
- Bravery factor, 80, 81
- Carnot efficiency, 129
- Catch-22, 94
- CEBAF, 164, 165
- CESR, 134
- Chaos, 45, 47–49, 102, 106, 180, 181
 - weak, 190
- Characteristic equation, 26
- Chromaticity, 40, 84, 94, 184
 - correction, 94, 96
 - FODO, 96
 - solution, 97
 - goal, 97
 - natural, 95, 96, 168
- Classical radius, 121, 172
- CLIC, 159
- Co-ordinate convention, 14
- Coherent synchrotron radiation, 162
- Compaction factor (also see Slip factor), 44, 121, 134, 139
- Cooling, 7, 9
- Coupling, 53, 184
 - horizontal and vertical, 24, 84, 88, 138
- Courant–Snyder invariant, 51, 61, 135
- Cryomodule
 - magnet, 69
 - RF, 142, 152, 153, 160

202

Damping, 116, 180
 adiabatic, 58, 60, 116
 decrement, 140
 horizontal, 135
 longitudinal, 121, 133
 time
 characteristic, 60, 116, 126, 128, 139
 horizontal, 127
 longitudinal, 123, 124
 vertical, 126
 vertical, 126
 Decapole, 84, 108, 188
 Design and closed orbits, 3, 13
 Detuning (see Tune), 107
 Diffusion
 Arnol'd, 190
 modulational, 190
 Dipole, 16, 63, 65, 67, 70, 192, 193
 motion, 20
 packing fraction, 34
 pole-face rotation, 20, 192
 window-frame, 70
 Dispersion
 differential equation, 39
 FODO cell minima and maxima, 41, 48
 function, 39, 133, 184
 matrix propagation, 40
 one-turn matrix solution, 41, 49
 polynomial expansion, 39
 suppressor, 32, 40
 Dodecapole, 114

 E778, 187, 189
 Eigenfrequencies, 88
 Eigenvalues and eigenvectors, 25, 26, 35
 Emittance
 dynamic equilibrium, 59, 116, 128
 horizontal, 134, 136, 137, 139
 implicit distribution shapes, 59
 longitudinal
 normalised, 60
 phase space area, 60, 62
 normalised, 59
 phase space area (linac), 56, 59
 unnormalised, 53, 56
 vertical, 138, 139
 Energy
 centre-of-mass, 7
 stored in the beam, 9
 Errors and their corrections, 83, 84
 β -function (see Twiss), 86
 closed orbit and trajectory, 83,
 85, 86
 dipole kick, 84
 three-bump, 86, 87, 92
 Injection
 angle, 61
 displacement, 55, 57

Index

 momentum, 57
 optics, 61
 linear coupling, 89
 quadrupole strength, 90, 93
 linear optics stability, 92
 tune shift, 90
 roll misalignment
 dipole, 84, 138
 quadrupole, 88, 92, 138
 transverse misalignment
 dipole, 84
 multipole, 83
 quadrupole, 84, 138
 ESS, 141, 142, 144, 156
 Excitation, 116
 longitudinal, 133
 quantum
 betatron, 134, 135, 140
 longitudinal, 132
 strength, 132
 RF noise, 133, 135

 FCC, 129
 Feed-down (see Magnet multipole), 68
 Filamentation, 50, 54, 55
 Fixed point, 175, 177
 stable, 177
 unstable, 179
 Fixed target accelerator, 6
 Floquet transformation, 27
 Free electron laser, 10, 162
 FRIB, 141, 142

 Gauss' law, 171

 Hamiltonian
 continuous acceleration, 124, 125
 contours, 46, 111, 112, 125
 Kobayashi, 100, 104, 109–112, 174, 182, 184
 one-turn, 109, 110
 pendulum, 46, 184
 projection, 104
 resonance, 176–178, 182, 184, 185
 separatrix, 178
 sideband, 185
 standard map, 46, 184
 two-turn, 111, 112, 115
 valley and lakes, 124, 125
 Harmonic number, 44
 Head–tail effect, 97
 HERA, 12
 Hill's equations, 37, 93
 generalised, 38
 off-momentum free oscillations, 40

 ILC, 159
 Injection transients (see Filamentation), 50

- KAM surface, 48, 108, 109
- Kilpatrick criterion, 80, 81
- Laplace's equation, 72
- Larmor acceleration and radiation, 116, 117
- Lattice and optics, 13, 16, 24
 - achromats – DBA and TBA, 138, 139
 - Chasman-Green, 138
 - dispersion suppressor, 32, 40
 - doublet, 34, 152, 158
 - FODO, 25, 32, 135, 136, 138, 139, 161, 164
 - $\mathcal{H}$, 136, 137
 - chromaticity, 94
 - injection straight, 58
 - matched, 32
 - stability with quad error, 92
 - telescope, 32
- LCLS-II, 159, 160, 162
- LEP, 129, 134
- LHC, 134
- Linac, 10, 34, 50, 56
 - H^- , 143
 - intra-beam stripping, 157
 - stripping, 144
- acceleration
 - off-crest, 149, 151, 160
 - on-crest, 148, 160, 164
 - on-trough, 166
- beam breakup BBU, 166
 - multi-bunch, 168
 - regenerative, 168
 - regenerative threshold, 169
 - single bunch, 167
 - single bunch BNS damping, 168, 169
- beam power, 142
- bunch compressor, 160, 162, 163
 - chicane, 162, 163, 169
- drift tube DTL, 141, 147, 152
- electron, 141, 146, 159
 - RF capture, 161
- energy recovery ERL, 164
 - multi-pass, 165, 166
 - single-pass, 165, 166
- focusing
 - longitudinal, 160, 162
 - over-focusing, 157, 161
 - radial defocusing, 149–151, 153, 161
 - transverse, 151, 161, 168
- ion, 141
- ion source, 142
- proton, 141
 - beam loss, 157
 - continuous waveform, 144
 - duty factor, 144
 - effective drift length, 158
 - frequency doubling, 144
 - high power, 141, 144, 157
 - macropulse, 142–145
 - technology map, 144
 - recirculating RLA, 164–166
 - reference phase, 148
 - side coupled, 141
 - technology map, 159
 - electron, 159, 160
 - proton, 141, 142
- Liouville's theorem, 55
- Longitudinal
 - β -function, 60–62
 - motion
 - damped, 121
 - difference equations, 44, 123
- Lorentz
 - electromagnetic field transformations, 128
 - equation, 7, 113
 - force, 16, 66
 - cavity detuning, 80
 - invariant – radiated power, 117
- Luminosity, 8, 170
 - round beam, 174
- Lyapunov exponent, 48, 49, 102, 106, 182
- Magnet
 - air-cooled or water-cooled, 70
 - combined function, 22, 24, 64, 193
 - field index, 193
 - conductor-dominated, 17, 66
 - $\cos(\theta)$, 66
 - field error harmonics, 65, 67
 - allowed and disallowed, 65, 68
 - random and systematic, 68
 - reference radius, 68
 - trends, 68
 - iron-dominated, 17, 65
 - boundary condition, 65
 - saturation, 65
 - lithium lens, 71
 - misalignment
 - conductor, 68
 - installation, 68
 - multipole
 - coefficient, 63
 - feed-down, 68, 84, 138
 - nonlinear, 170
 - normal or skew, 63
 - pole-tip field, 67, 71
 - scalar potential, 71, 72
 - sorting, 68
 - stored energy, 71
 - superconducting, 63, 66
 - phase transition, 66
- Magnetic rigidity, 16, 19, 22
- Map
 - control parameter, 10, 99–101, 181, 183, 185
 - Hénon, 94, 98, 100, 103, 105–107, 130, 140, 181
 - logistic, 10

204

Map (cont.)
 octupole
 many, 110–112
 one, 106–108
 projection, 104
 standard, 2, 4, 45, 49, 177, 181, 184
 two sextupole FODO cell, 105

Matrix
 acceleration, 196
 black box, 36
 combined function bend, 193
 dipole, 20
 rectangular RBEND, 193
 sector SBEND, 192
 drift, 20, 191
 Floquet transformation, 27
 FODO, 32, 35
 one-turn, 24, 26, 35
 partial turn (see Partial turn), 29
 quadrupole, 21, 194
 rolled, 92, 195
 skew, 195
 thin, 20
 rolled magnet, 195
 rotation
 co-ordinate, 27
 pole-face, 192
 solenoid, 195
 thin, 151

Maxwell's equations, 16, 63, 69, 71, 149

Modulation
 amplitude modulation, 186
 phase modulation, 102, 185
 power supply ripple, 184
 tune, 184, 190
 amplitude q , 184, 187, 189, 190
 chirp, 189
 fast, 185, 187
 slow, 186, 187
 tune Q_M , 184, 187, 190

Multiple Coulomb scattering, 62

Muon, 12, 129

N-turn motion, 102, 182, 184
 1, 24, 25, 27, 99, 107–110
 2, 110–112, 115
 3, 99, 110
 5, 102, 182
 beam-beam, 175, 182

Natural electron
 emittance
 horizontal, 134, 136, 137, 139
 vertical, 138
 energy spread, 132–134, 140

Neutrino, 12

NSLS VUV, 138

NSLS-II, 121, 134

Index

Octupole, 83, 84, 106–108, 111, 112, 115, 188

Partial turn propagation
 action-angle co-ordinates, 52
 after a horizontal kick, 35
 dispersion, 40
 phase (see Twiss), 30
 phase space, 29
 Twiss functions (see Twiss), 29

Particle-antiparticle collisions, 7

Partition number, 127
 horizontal, 137
 longitudinal, 134

Path length, off-momentum, 42

Pendulum, 1, 4, 45
 characteristic frequency, 88
 coupled, 88

PEP, 138

Permittivity and permeability, 74, 117

Persistent signal, 187, 189

Phase space
 co-ordinates, 3
 ellipse, 4
 longitudinal, 60
 normalised, 27, 29, 35, 52

Pion, 12

PIP-II, 141–143

Planck constant, 128, 131

Poincaré
 discovery of chaos, 48
 surface of section, 4, 190

Positrons, 7

Quadrupole, 16, 18, 63, 65, 67, 68, 71, 152, 194
 field and gradient, 18
 geometric strength, 19
 motion, 18
 skew, 22, 84, 89, 92, 138, 195

Quadrupole-sextupole pair, 95

Resonance, 83, 94
 1-D, 170, 174, 182
 action, 175, 182
 coupling diagonal, 89
 drive, 98
 half-integer, 92, 104
 Hamiltonian (see Hamiltonian), 176
 integer, 86, 104
 island, 47, 100–102, 104–106, 130, 140, 176–189
 island action, 184
 island chain, 177–180, 183
 sideband, 185, 186
 island trapping, 187, 189
 island tune Q_I , 177, 180, 182, 187
 island width, 178, 179, 182
 linear, 83
 lines, 92, 98, 103, 104
 order, 98

- overlap, 183, 186, 187, 190
- phase-lock, 102, 177, 179, 187
- sideband, 185, 187
- RF
 - bucket, 124–126
 - capture, 161, 162
 - cavity, 15, 73
 - beampipe, 78, 149
 - couplers, 78
 - crab, 74
 - elliptical, 79, 80, 160
 - exotic, 79
 - geometric β_G , 146
 - pill-box, 44, 76, 81
 - shunt impedance, 81
 - single-cell and multi-cell, 80, 159
 - superconducting, 80
 - thin approximation, 147
 - field emission, 80
 - mode
 - accelerating and fundamental, 76, 77
 - cut-off frequency, 75
 - damped and propagating, 73, 75
 - higher-order HOM, 74, 76, 79, 80, 159, 166–168
 - indices mnp , 77, 79
 - pill-box, 76
 - resonant, 76
 - transverse TE, TM, TEM, 74, 77, 78, 81, 149
 - wave number, 73–75
 - travelling wave, 73, 159, 161
 - phase velocity, 73
 - waveguide, 73
 - boundary conditions, 73
 - co-ordinates, 74
- RFQ, 141–143, 151, 153
 - A and X efficiencies, 155
 - advantages and disadvantages, 157
 - control parameters, 156
 - electric fields, 155
 - linearised, 156
 - Kapchinsky–Teplyakov potential, 154
 - modulation parameter, 153, 154
 - vaness, 153, 154
- RHIC, 9, 11, 15, 95, 113, 129
- Rigidity (magnetic), 16, 19, 22
- Ring
 - H^- accumulation and compression, 143, 144, 157
 - combined function, 128
 - equatorial, 129
 - isomagnetic, 121, 131, 133, 134, 136, 137
 - separated function, 24, 128
 - storage
 - collider, 7, 95
 - electron light source, 119, 120, 140
 - electron–positron collider, 139, 170, 180
 - hadron–hadron collider, 170, 180
 - muon, 129
- Septum, 111–113, 115
- Sextupole, 64, 65, 69, 83, 84, 94, 98, 101, 104, 107, 170
 - families, 96
- Slip factor (also see Compaction factor), 43, 49, 61
- Slow extraction, 102, 105, 107, 111–113
- Smear, 114
- SNS, 141–143
- Solar system, 4
- Solenoid, 22, 151, 195
- Space charge
 - cf beam–beam, 172, 180
 - proton linac, 141, 153, 158
- Spoke resonators, 141
- Spread
 - energy (see Natural electron), 132
 - momentum (see Beam size), 60
 - tune (see Tune), 55
- SSC, 11
- Strange attractor, 124, 126, 130, 140
- Strong focusing, 24, 25
- Synchronism factor, 146, 159
- Synchronous
 - particle, 122, 124
 - phase, 122, 130
- Synchrotron frequency (see Tune), 130
- Synchrotron radiation, 10, 116, 180
 - characteristic energy, 131, 139
 - characteristic frequency, 118
 - characteristic wavelength, 118
 - damping (see Damping), 116
 - distribution pattern, 116, 119, 128
 - energy loss per turn, 119, 139
 - variation with momentum, 123, 124
 - excitation (see Excitation), 116
 - ions and muons, 129
 - opening angle, 119
 - spectrum
 - power, 116, 118, 131
 - quantum, 131
- Tape drive, 3, 22
- Time-of-flight energy measurement, 147
- Total horizontal displacement, 38, 39
- Trajectory
 - chaotic, 102, 182
 - rapidly divergent, 102, 103, 111, 112, 181
 - regular non-resonant, 100, 181
 - regular resonant, 101, 181
- Transit-time factor
 - general, 145
 - pill-box, 79, 81, 145
- Transition
 - crossing, 44, 61
 - jump, 44
 - gamma, 42
 - imaginary, 44

206

- Tune
 - amplitude dependence, 84, 98, 107, 108, 113, 114, 179, 182
 - betatron, 13, 29, 30
 - closest approach of eigentunes, 89
 - footprint, 95
 - island (see Resonance island tune), 177
 - plane, 92, 95, 98, 104, 113
 - shift, 90, 93
 - sideband, 185
 - spread, 54, 55, 94, 97
 - chromatic, 95, 97
 - standard map, 46, 49
 - synchrotron, 15, 45, 46, 49, 61, 62, 130, 181, 184
 - working point, 97, 98
- Tune modulation (see Modulation, tune), 184
- Tune modulation space, 187
 - normalised, 187, 190
 - universal boundaries, 187–190

Index

- Twiss
 - β -function, 27, 32
 - differential equation, 91
 - error wave, 86, 90, 91, 93
 - FODO cell minima and maxima, 33, 34, 49
 - propagation, 197
 - propagation in a drift, 35, 91
 - three-bump, 92
- functions α, β, γ , 27, 50, 56, 133
 - parameterising optics or beam?, 50
 - propagation, 29, 35, 196, 197
- identity, 51, 56
- phase
 - propagation, 30, 35, 196, 197
- Wakefield, 159, 167
- XFEL, 159