

## Index

- angular momentum  $\vec{J}$ , 24  
 anomaly, quantum anomaly, 449  
 anti-unitary operator, 21, *see also*  
     time reversal  
 associated production, 74, 119  
 asymptotic states  
     in and out states, 39  
 axial vectors, 12  
 axion, 324  
     invisible, 328  
     visible, 326
- B* decays  
      $b \rightarrow s\gamma$   
         SUSY, 428  
      $B \rightarrow \mu^+\mu^-$ , 259  
      $B \rightarrow K^*\gamma$ , 258  
      $B \rightarrow X\gamma$   
         SUSY, 429  
      $B \rightarrow X\nu\bar{\nu}$ , 260  
      $B \rightarrow X_s\mu^+\mu^-$ , 261  
         long distance correction, 261  
      $B \rightarrow \gamma X$ , 258  
      $B \rightarrow \pi\pi$ , 222, 223  
      $B \rightarrow DK$ , 225  
      $B \rightarrow \rho\pi$ , 224  
      $B \rightarrow VV$ , 219  
      $B_s \rightarrow K_S\rho^0$ , 238  
      $B_d \rightarrow \phi K_S$ , 238  
      $B_s \rightarrow \psi\phi$ , 237  
      $B_s \rightarrow D_s^\pm K^\mp$ , 240
- dilepton events, 187  
 experiment  
     ALEPH, 184  
     ARGUS, 185  
     CDF, 184  
     DELPHI, 184  
     MAC, 184  
     MARK II, 184  
     OPAL, 184  
     PEP II, 184  
 flavour-non-specific, 104  
 flavour-specific, 103  
 impact parameter  $\delta$ , 184  
 lepton tag, 186  
 lifetime, 183  
 NFC, 390  
 penguins  
      $B \rightarrow \pi^+\pi^-$ , 222  
      $B \rightarrow \psi K_S$ , 218  
     pollution, 215  
 rare decays, 248  
 $y_s$ , 235
- B* meson  
 C of  $B - \bar{B}$  system, 186  
 $\Delta M_B$ , 188  
 $\Delta\Gamma$   
      $B_d, B_s$ , 230  
 discovery of  $B - \bar{B}$  mixing, 186  
 experiment  
     ARGUS, 186  
 $\Gamma_{12}$ , 231

- lifetime, theoretical estimate, 185
- $\Delta M_B$ , 192
- theory
  - $\Delta M_B$ , 190
  - $\Delta\Gamma$ , 232
  - $x_d$ , 191
  - $x_s$ , 192
  - $x_d$ , 188
- bag factor, 166, 173
- baryogenesis, 362, 393
  - electroweak, 448
  - GUT, 446
- Bell–Steinberger inequality, 110
- black hole, 265
- box diagrams
  - K, 173
  - QCD correction, 173
- broken  $R$  parity, 406
  
- Cabibbo-suppressed decays, doubly, 228
- charge conjugation
  - of  $B^0 - \bar{B}^0$  system, 186
  - definition (**C**), 12
  - electrodynamics, 17
  - quantum mechanics, 25
  - spin 0 fields, 47
  - spin 1/2 fields, 51
  - spin 1 fields, 43
- chiral perturbation theory, 250
- chiral symmetry
  - VSA, 165
    - factorization, 166
- chiral transformation, 318
- CKM matrix, 150
  - $\eta$ , 154
  - numerical values, 208
  - $\phi_3$ , 225
  - $\rho$ , 154
  - unitarity relations, 154
  - $\mathbf{V}_{td}$ , 236
  - $\mathbf{V}_{ts}$ , 236
  - Wolfenstein parametrization, 154
- coherent production of  $D$  pairs, 310
- Coleman–Mandula theorem, 413
- cosmic domain wall problem, 403
  
- CP**
  - $B \rightarrow \bar{B}$  mixing, 193
  - direct **CP** violation, 111, 118, 169
    - $\frac{\epsilon'}{\epsilon}$ , 118
  - experiment
    - CPLEAR, 117
    - $\delta_l$ , 117
    - discovery of, 87
    - E731, 118
    - E832, 118
    - $\eta_{00}$ , 117
    - $\eta_{+-}$ , 117
    - NA31, 117, 118
    - $\phi_{+-}$ , 127
    - $\phi_{00}$ , 127
  - hard **CP** breaking, 158
  - indirect **CP** violation, 111
  - KM ansatz, 149
  - millistrong  $H_{MS}$ , 143
  - milliweak  $H_{MW}^-$ , 144
  - $\phi$ , 94, *see also* symmetry
  - strong **CP** problem, 147
  - superweak  $H_{SW}$ , 144
  - violation
    - with  $B - \bar{B}$  mixing, 100
    - flavour-specific, 229
    - leptonic asymmetry, 232, 233
    - in  $\mu$  decays, 402
    - in positronium decays, 401
    - in production, 398
    - QCD vacuum, 315
    - sign of, 106
    - spontaneous, 363, 375
    - supersymmetry, 421
    - in  $\tau$  decays, 403
    - time dependent, 198
  - violation in,  $B^0 \rightarrow \psi K_S$  decay, 194
- CPT**, 265
  - constraint on,  $\mathcal{A}_I$ , 125
  - $B$  decays,  $s$ -**CPT** parameter, 282
  - $\cos \theta$ , 94, *see also* symmetry
  - effective **CPT** asymmetry, 109
  - experiment
    - $\phi_{+-}$ , 127
    - $\phi_{00}$ , 127
    - $\text{Re } \cos \theta$ , 281

- CPT** (cont.)  
 leptonic K decay, 269  
 masses and lifetimes, 266  
 Maxwell's equation, 16  
 tests of,  $B$  decays, 281
- CPT** constraints, 67
- current quarks, constituent quarks, 383
- $D - \bar{D}$  oscillations, 288
- Dalitz plots, 301
- $\Delta\Gamma$   
 $B_d, B_s$ , 230  
 theory, 232
- $\Delta I = 1/2$  rule, 76, 167
- $\Delta M$  definition, 97, *see also* symmetry
- $\Delta M_B$ , 188  
 sign, 192  
 theory, 190
- $\Delta M_K$ , theory, 174
- $\Delta S = 2$   
 amplitudes, 172  
 effective Hamiltonian, 173
- $\Delta S = \Delta Q$  rule, 82, 271
- $\delta_l$ , 129
- detailed balance, 32
- Dirac matrices, 43
- domain wall, 322
- EDM**  
 atomic, 35  
**CP** odd gluonic operators, 386  
 definition, 33  
 degeneracy, 34  
 experiment, 35  
   Cs atom, 38  
   search, 35  
 generated by  $\theta$ , 320  
 induced, 320  
 in models with NFC, 385, 387  
 neutron, 33, 319  
 Schiff's definition, 37  
 Schiff's theorem, 37  
 SUSY, 427  
   water molecule, 35  
 elastic unitarity, 63
- EPR correlations, 250
- $\epsilon$ , 126  
 experiment  
   CPLEAR, 117  
   NA31, 117  
 in models with FCNC, 389  
 phase of, 127  
 theory, 175
- $\epsilon'$ , 125  
 experiment  
   E731, 118  
   E832, 118  
   NA31, 118  
 prospective, 172  
 theory, 168, 170
- $\eta$ , 154
- explicit symmetry breaking, 42, *see also* symmetry
- factorization approximation, 166
- FCNC, 389  
 $\Delta C = 2$  transitions, 390
- final state interaction, 26, 58, 65, 69  
 fake **T** odd correlations, 67  
 K leptonic decay,  $P_\perp$ , 130  
 $\pi\pi$  phase shift, 121  
 Watson's theorem, 62
- fine tuning, 414
- four-Fermi operators, 217
- $G$  party, 62
- $\Gamma$ , 107
- $\Gamma_{ij}$ , 92, *see also* symmetry  
 $\text{Im}\Gamma_{12}$ , 275
- gauge hierarchy problem, 415
- GIM, 145, 249  
 super-GIM, 422
- GIM mechanism, 291
- grand unified theories (GUT), 414
- gravitino, 420
- groundstate, degeneracy, 42
- hadronization, 209
- Hamiltonian  
 charged current, 160  
 $\Delta B = 1$ , 217

- $\Delta S = 1$ , 164
- $\Delta S = 2$ , 173
- effective,  $P - \bar{P}$ 
  - mixing, 90
- hard **CP** breaking, 10
- helicity, 219
- hyperon
  - decays, 67
  - experiment, 140
  - $\Lambda \rightarrow N\pi$ , 138
  - $\Xi \rightarrow \Lambda\pi$ , 139
- intrinsic parity
  - fermions, 50
  - $p, n, e, \pi, 60$
- $J/\psi$ , 152
  - discovery of, 181
- $K$  decays
  - $A_{CPT}(t)$ , 272
  - $A_T$ , 129
  - $A_T(t)$ , 272
  - box diagrams, 173
    - QCD correction, 173
  - $\Delta M_K$ , theory, 174
  - $\Delta S = 2$ 
    - amplitudes, 172
    - effective Hamiltonian, 173
  - $\delta_l$ , 129
  - $\epsilon$ 
    - phase of, 127
    - theory, 175
    - without **CPT**, 273
  - $\epsilon'$ , 125
    - prospective, 172
    - theory, 168, 170
    - without **CPT**, 273
  - $\eta$ , phases of, 274
  - experiment
    - CPLEAR, 271
    - E787, 252
    - E832, 257
    - $K^+ \rightarrow \pi^+\nu\bar{\nu}$ , 252
    - $\phi_{+-}$ , 127
    - $\phi_{00}$ , 127
  - $F_l$ , 128
  - flavour-non-specific, 104
  - flavour-specific, 103
  - $K_L \rightarrow l^\pm\nu\pi^\mp$ , charge asymmetry, 270
  - $K \rightarrow \mu\nu\pi$ , in models with NFC, 388
  - $K \rightarrow \pi\nu\bar{\nu}$ , 251
  - $K^+ \rightarrow \pi^+e^+e^-$ , 248
  - $K^+ \rightarrow \pi^+ + X^0$ , 252
  - $K^\pm \rightarrow \pi^\pm\pi^+\pi^-$ , 138
  - $K^\pm \rightarrow \pi^\pm\pi^0\gamma$ , 254
  - $K_L \rightarrow \pi\pi$  decay, 117
  - $K_L \rightarrow \mu^+\mu^-$ , 248
  - $K_L \rightarrow \pi^0\nu\bar{\nu}$ , 253
  - $K_L \rightarrow \pi^+\pi^-\pi^0$ , 273
  - $K_S \rightarrow 3\pi^0$ , 133
  - $K_S \rightarrow \pi^+\pi^-\pi^0$ , 133
  - non-leptonic, 160
  - rare decays, 248
  - $s \rightarrow d\gamma$ 
    - charge radius, 249
    - magnetic moment, 249
  - $x_l$ , 128
  - $y_l$ , 128
  - $K$  meson
    - $\Delta M_K, \Delta\Gamma_K$ , 82
    - discovery of **CP** violation, 86
    - $\epsilon(f)$ , 275
      - $f = \pi\mu\nu$ , 276
    - $K - \bar{K}$  mixing, 77
    - $K_L$  versus  $K_S$ , 79
    - mass eigenstates, 79
    - regeneration, 83
    - Rochester and Butler, 74
    - semileptonic  $K_L$  decay, 121
    - sign of  $\Delta M$ , 83, 98
    - transverse polarization,  $K$  leptonic decay, 129
  - Kabir test, 121, *see also* time reversal and symmetry
  - KM ansatz, 149
  - KM definition, 8
  - Kramer's degeneracy, 30, *see also* time reversal

- leading log, 161  
 left–right symmetry, 363  
    $\Delta M$ , 369  
    $\Delta S = 2$  transition, 368  
    $\Delta S = 1$  transitions, 370  
   EDM, 372  
    $\epsilon$ , 369  
    $\epsilon'$ , 371  
    $K$  decays  
      $K^+ \rightarrow \mu^+ \nu \pi^0$ , 372  
   limits on, 367  
   manifest, 365  
   pseudo, 366  
   seesaw mechanism, 363  
    $W_L - W_R$  mixing, 365  
 leptogenesis, 400  
 leptoquarks, 403  
 long-lived axions, 328  
  
 Majorana mass, 367  
 Mass Insertion approximation, MI,  
   426, 431  
 mass matrix, diagonalization, 93  
 Maxwell's equations  
   **C, P, T** transformation  
     property, 16  
     Lorentz covariant form, 43  
    $M_{ij}$ , 92, *see also* symmetry  
 minimal electromagnetic  
   coupling, 25  
 minimal flavour violation,  
   MFV, 436, 439  
 MNK matrix, 401  
 MSSM, 416  
 MSW effect, 349  
 multi-Higgs model  
    $\Delta C = 2$  transitions  
     FCNC, 390  
    $\epsilon$   
     in models with FCNC,  
       378, 389  
     NFC, 383  
    $\epsilon'$   
     NFC, 383  
     FCNC, 377  
     NFC, 376, 382  
  
   EDM, 385  
    $P_\perp(\mu)$ , in models with NFC, 388  
   multiplicative renormalization, 161  
  
 natural flavour conservation, 377  
 neutrino  
   atmospheric, 340  
   Dirac, 352  
   Majorana, 352  
   mass, 350  
   oscillations, 343  
     **CP** and **T** violation, 356  
     seesaw mechanism, 353  
   solar, 336  
 neutrino, atmospheric  
   experiments  
     IMB, 341  
     Soudan, 341  
     Superkamiokande, 341  
 neutrino oscillations  
   experiments  
     GALLEX, 337  
     Homestake, 337  
     Kamiokande, 337  
     SAGE, 337  
 New Physics, 236, 238  
   and  $B_s$  transitions, 430  
 New Physics Flavour Problem, 413  
 NFC, 365, 376  
   beauty decays, 390  
   EDM, 385  
 non-minimal Higgs dynamics, 397  
 non-perturbative dynamics, 396  
 non-renormalization theorems of  
   SUSY, 415  
 nucleosynthesis, 444  
  
 operator  
   anti-unitary, 21  
   complex conjugation, 21  
   product expansion, 161  
   operator mixing, 163  
    $\langle Q_i \rangle$ -numerical evaluation,  
     169  
   operator product expansion, 437

- $P_{\perp}(\mu)$   
 in models with NFC, 388  
 parity  
   classical mechanics, 13  
   definition ( $\mathbf{P}$ ), 12  
   electrodynamics, 17  
   intrinsic, 25  
   quantum mechanics, 22  
   spin-0 fields, 46  
   spin-1/2 fields, 49  
   spin-1 fields, 43  
 Pauli matrices, 43  
 Peccei–Quinn symmetry, 323  
 penguin, 238  
 penguins  
    $B \rightarrow \pi^+ \pi^-$ , 222  
    $B \rightarrow \psi K_S$ , 218  
   electromagnetic, 164  
   enhancement, 167  
   operators, QCD, 162  
   pollution, 215  
   quark diagrams, 203  
 phase conventions, 23, 25, 59, 95  
   independence of, 111  
   internal symmetry, 61  
   phase factor, 30  
   Wu–Yang, 124  
 $\phi_{+-}$ , 127  
 $\phi_{00}$ , 127  
 $\phi_3$ , 225  
 $\phi$  factory, 119, 279  
 photon field, 45  
 PMNS matrix, 355  
 polarization vector  
    $\mathbf{C}$ ,  $\mathbf{P}$ ,  $\mathbf{T}$  symmetry, 45  
 pseudoscalars, 12  
  
 $\frac{q}{p}\bar{\rho}(f)$ , phase independence, 111  
 QCD corrections, 161  
 QCD vacuum, 315  
    $\mathbf{CP}$  violation, 315  
 quadratic mass renormalization, 414  
 quantization conditions  
   spin-1/2 fields, 48  
   spin-0 field, 46  
   spin-1 field, 44  
  
 quantum anomaly, 317, 319  
 quantum mechanics  
   going beyond, 88  
   non-linear, 88  
   test of, 265  
 quantum numbers  
   additive, 75  
   multiplicative, 75  
 quantum states, pure versus mixed, 228  
  
 rare decays,  $K$ ,  $B$ , 248  
 reciprocity relation, 32  
 regeneration  
   mimicking  $\mathbf{CPT}$  violation, 109  
   formalism, 108  
 renormalization group, 161  
 $\rho$ , 154  
 $\rho - \eta$  plane, 208  
  
 Sakharov conditions, 445  
 scalars, 12  
 Schiff's theorem, 37, *see also* EDM  
 Schrödinger equation, 22, 28  
 Scylla and Charybdis problem, 165  
 seesaw mechanism, 353, 363  
 short-lived axions, 328  
 SM definition, 4  
 soft  $\mathbf{CP}$  breaking, 11  
 soft  $\mathbf{CP}$  violation, 322  
 soft SUSY breaking, 416  
 solar neutrino, 336  
 spin operator  $\vec{S}$ , 28  
 spin-0 fields, 46  
 spin-1/2 fields, 48  
 spin-1 fields, 43  
 spontaneous  $\mathbf{CP}$  violation, 363  
 spontaneous symmetry breaking, 42  
 strangeness, 74  
 strong  $\mathbf{CP}$  problem, 147  
 supergravity, 414  
 superposition principle, 21  
 supersymmetry, 412  
    $B$  decays  
      $b \rightarrow s\gamma$ , 428  
      $B \rightarrow \gamma X_s$ , 429

- supersymmetry (cont.)  
    $B^0 - \bar{B}^0$  oscillations, 430  
   CP violation, 421  
   EDM, 427  
   GIM, super-GIM, 422  
   gravitino, 420  
    $K^0 - \bar{K}^0$  oscillations, 428  
   MSSM, 417  
   non-MSSM, 425  
 supertrace, 418  
 superweak  $H_{SW}$ , phase  
    $\phi_{SW}$ , 126  
 SUSY breaking, 417, 419  
 SUSY Flavour Problem, 431  
 symmetry  
   breaking of  
     explicit, 42  
     spontaneous, 42  
   definition, 41  
   ground state, 41  
   transformation properties  
      $\cos \theta, \phi$ , 94  
     fermion bilinears, 54  
     fields, 54  
      $\text{Im}M_{12}, \text{Im}\Gamma_{12}$ , 93  
     Lagrangian, 56  
     masses and lifetimes, 56  
  
**T** odd correlation, 399  
**T** odd moment, 406  
 $\tau$  decay, dilepton  
   correlation, 404  
 theoretical engineering, 268  
 $\theta_{QCD}$ , 321  
 $\theta - \tau$  puzzle, 75  
 time dependent decay  
    $A_{+-}(t)$ , 119  
    $f_{\pm}(t)$ , 100  
    $K_{\pm}(t)$ , 100  
    $\langle K_{\pm} \rangle$ , 107  
    $L^*(t)$ , 100  
    $\langle L^* \rangle$ , 107  
    $P(t) \rightarrow f$  and  $\bar{P}(t) \rightarrow f$ , 104  
    $x$ , 107  
    $y$ , 107  
 time reversal  
  
 anti-unitary operator,  
   21, 27  
   Hermitian conjugation  
     of, 22  
 classical mechanics, 14  
 definition (**T**), 12  
 electrodynamics, 17  
 electromagnetic fields, 17  
 experiment,  $A_T$ , 121  
 initial conditions,  
   16, 22  
 Kabir test, 121  
 Kramer's degeneracy, 30  
 Ohm's law, 19  
 quantum mechanics, 26  
 reversal of motion, 12  
 spin-0 fields, 47  
 spin-1/2 fields, 52  
 spin-1 fields, 43  
 spin operator  $\vec{S}$ , 28  
**T** odd correlation, 67  
   top decay, 399  
 transverse polarization  
    $K$  leptonic decay, 129  
   theoretical formulation, 132  
   experiment, 132  
 top quark, 396  
   decay, 399  
 transverse polarization,  $K$  leptonic  
   decay, 129  
  
 unitarity triangle,  
   151, 154  
 universality, 152  
 $\Upsilon(4S)$   
   decays of, 199  
   discovery of, 180  
   production cross  
     section, 200  
  
 vacuum expectation values,  
   VEVs, 414  
 vacuum saturation  
   approximation, 173  
 vectors, 12  
 VSA, 165

- Watson's theorem, 62, 121  
 weak universality, 149  
 Weisskopf–Wigner  
   approximation, 91  
 Wolfenstein  
   parametrization, 154  
  
 $x$ , 107, *see also* time dependent decay  
 $x_d$ , 188  
   theory, 191  
  
 $x_l$ , 128  
   experimental data, 271  
 $x_s$ , theory, 192  
 $\xi$ , 132  
  
 $y$ , 107, *see also* time dependent decay  
 $y_l$ , 128  
 $y_s$ , 235  
 Yukawa couplings, 397