Notation

Position vectors in three-dimensional space are denoted by $\mathbf{r} = (x, y, z)$, or $\mathbf{x} = (x^1, x^2, x^3)$ where $x^1 = x, x^2 = y, x^3 = z$.

A general vector $\mathbf{a}$ has components (a^1, a^2, a^3), and $\hat{\mathbf{a}}$ denotes a unit vector in the direction of $\mathbf{a}$.

Volume elements in three-dimensional space are denoted by $\mathrm{d}^3\mathbf{x} = \mathrm{d}x\mathrm{d}y\mathrm{d}z = \mathrm{d}x^1\mathrm{d}x^2\mathrm{d}x^3$.

The coordinates of an event in four-dimensional time and space are denoted by $x = (x^0, x^1, x^2, x^3) = (x^0, \mathbf{x})$ where $x^0 = ct$.

Volume elements in four-dimensional time and space are denoted by $\mathrm{d}^4x = \mathrm{d}x^0\mathrm{d}x^1\mathrm{d}x^2\mathrm{d}x^3 = c\,\mathrm{d}t\,\mathrm{d}^3\mathbf{x}$.

Greek indices μ, ν, λ, ρ take on the values 0, 1, 2, 3.

Latin indices *i, j, k, l* take on the space values 1, 2, 3.

Pauli matrices

We denote by σ^μ the set $(\sigma^0, \sigma^1, \sigma^2, \sigma^3)$ and by $\tilde{\sigma}^\mu$ the set $(\sigma^0, -\sigma^1, -\sigma^2, -\sigma^3)$, where

$$\sigma^0 = \mathbf{I} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \ \sigma^1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \ \sigma^2 = \begin{pmatrix} 0 & -\mathrm{i} \\ \mathrm{i} & 0 \end{pmatrix}, \ \sigma^3 = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix},$$

$$(\sigma^1)^2 = (\sigma^2)^2 = (\sigma^3)^2 = \mathbf{I}; \quad \sigma^1\sigma^2 = \mathrm{i}\sigma^3 = -\sigma^2\sigma^1, \text{ etc.}$$

Chiral representation for γ-matrices

$$\gamma^0 = \begin{pmatrix} \mathbf{0} & \mathbf{I} \\ \mathbf{I} & \mathbf{0} \end{pmatrix}, \ \gamma^i = \begin{pmatrix} \mathbf{0} & \sigma^i \\ -\sigma^i & \mathbf{0} \end{pmatrix},$$

$$\gamma^5 = \mathrm{i}\gamma^0\gamma^1\gamma^2\gamma^3 = \begin{pmatrix} -\mathbf{I} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} \end{pmatrix}.$$

Quantisation ($\hbar = c = 1$)

$$(E, \mathbf{p}) \to (\mathrm{i}\partial/\partial t, -\mathrm{i}\boldsymbol{\nabla}), \text{ or } p^\mu \to \mathrm{i}\partial^\mu.$$

For a particle carrying charge q in an external electromagnetic field,

$$(E, \mathbf{p}) \to (E - q\phi, \ \mathbf{p} - q\mathbf{A}), \text{ or } p^\mu \to \ p^\mu - qA^\mu,$$
$$\mathrm{i}\partial^\mu \to (\mathrm{i}\partial^\mu - qA^\mu) = \mathrm{i}(\partial^\mu + \mathrm{i}qA^\mu).$$

Field definitions

$$Z_\mu = W_\mu{}^3 \ \cos\theta_\mathrm{w} - B_\mu \ \sin\theta_\mathrm{w},$$
$$A_\mu = \mathrm{W}_\mu{}^3 \ \sin\theta_\mathrm{w} + B_\mu \ \cos\theta_\mathrm{w},$$

where $\sin^2\theta_\mathrm{w} = 0.2315(4)$

$$g_2 \ \sin\theta_\mathrm{w} = g_1 \ \cos\theta_\mathrm{w} = e, \quad G_\mathrm{F} = g_2{}^2/(4\sqrt{2}M_\mathrm{w}{}^2).$$

Glossary of symbols

$\mathbf{A}$	electromagnetic vector potential Section 4.3
A^μ	electromagnetic four-vector potential
$A^{\mu\nu}$	field strength tensor Section 11.3
A_{FB}	forward–backward asymmetry Section 15.2
a	wave amplitude Section 3.5
$a, a^\dagger$	boson annihilation, creation operator
$\mathbf{B}$	magnetic field
B^μ	gauge field Section 11.1
$B^{\mu\nu}$	field strength tensor Section 11.2
$b, b^\dagger$	fermion annihilation, creation operator
$\mathbf{D}$	isospin doublet Section 16.6
$d, d^\dagger$	antifermion annihilation, creation operator
d_k	($k = 1,2,3$) down-type quark field
$\mathbf{E}$	electric field
E	energy
$e, e_\mathrm{L}, e_\mathrm{R}$	electron Dirac, two-component left-handed, right-handed field
$F^{\mu\nu}$	electromagnetic field strength tensor Section 4.1
f	radiative corrections factor Sections 15.1, 17.4
f_{abc}	structure constants of *SU(3)* Section B.7
G^μ	gluon matrix gauge field
$\mathrm{G}^{\mu\nu}$	gluon field strength tensor
G_F	Fermi constant Section 9.4

$g^{\mu\nu}$	metric tensor
g	strong coupling constant Section 16.1
g_1, g_2	electroweak coupling constants
H	Hamiltonian Section 3.1
$h(x)$	Higgs field
$\mathcal{H}$	Hamiltonian density Section 3.3
$\mathbf{I}$	isospin operator Sections 1.5, 16.6
$\mathbf{J}$	electric current density Section 4.1
$\mathbf{J}$	total angular momentum operator
J	Jarlskog constant Section 14.3
J^{μ}	lepton number current Section 12.4
$\mathbf{j}$	probability current Section 7.1
j^{μ}	lepton current Section 12.2
K	string tension Section 17.1
$\mathbf{k}$	wave vector
$\mathbf{L}$	lepton doublet Section 12.1
L	Lagrangian Section 3.1
$\mathcal{L}$	Lagrangian density Section 3.3
l^3	normalisation volume Section 3.5
$\mathbf{M}$	left-handed spinor transformation matrix Section B.6
M	proton mass Section D.1
m	mass
$\mathbf{N}$	right-handed spinor transformation matrix Section B.6
N	number operator Section C.1
$\hat{\mathrm{O}}$	quantum operator
$\mathbf{P}$	total field momentum
$\mathbf{p}$	momentum
Q^2	$= -q_{\mu}q^{\mu}$
$\mathbf{q}$	quark colour triplet
q^{μ}	energy–momentum transfer
$\mathbf{R}$	rotation matrix Section B.2
$\mathbf{S}$	spin operator
S	action Section 3.1
s	square of centre of mass energy
T^{μ}_{ν}	energy–momentum tensor Section 3.6
$\mathbf{U}$	unitary matrix
u_k	$(k = 1, 2, 3)$ up-type quark field
$u_{\mathrm{L}}, u_{\mathrm{R}}$	two-component left-handed, right-handed spinors Section 6.1
u_{+}, u_{-}	Dirac spinors Section 6.3
$\mathbf{V}$	Kobayashi–Maskawa matrix Section 14.2

V	normalisation volume
$\mathbf{v}$	velocity
v	$= \lvert\mathbf{v}\rvert$
$v_{\mathrm{L}}, v_{\mathrm{R}}$	two-component left-handed, right-handed spinors
v_+, v_-	Dirac spinors Section 6.4
$\mathbf{W}^{\mu}$	matrix of vector gauge field Section 11.1
$\mathrm{W}^{\mu\nu}$	field strength tensor Section 11.2
$W^1_{\mu}, W^2_{\mu}, W^+_{\mu}, W^-_{\mu}$	fields of W boson
Z_{μ}	field of Z boson
$\alpha(Q^2)$	effective fine structure constant Section 16.3
$\alpha_s(Q^2)$	effective strong coupling constant Section 16.3
α_{latt}	lattice coupling constant Section 17.1
α^i	Dirac matrix Section 5.1
β	Dirac matrix Section 5.1
β	$= v/c$
Γ	width of excited state, decay rate
γ^{μ}	Dirac matrix Section 5.5
γ	$= (1-\beta^2)^{-1/2}$
δ	Kobayashi–Maskawa phase Section 14.3
$\boldsymbol{\varepsilon}$	polarisation unit vector Section 4.7
ε	helicity index
θ	boost parameter: $\tanh\theta = \beta,\ \cosh\theta = \gamma$ Section 2.1, phase angle, scattering angle, scalar potential Section 4.3, gauge parameter field Section 10.2
θ_{w}	Weinberg angle
Λ^{-1}	confinement length Section 16.3
Λ_{latt}	lattice parameter Section 17.1
λ_a	matrices associated with $SU(3)$ Section B.7
$\mu,\ \mu_{\mathrm{L}}, \mu_{\mathrm{R}}$	muon Dirac, two-component left-handed, right-handed field
$\nu_{e\mathrm{L}}, \nu_{\mu\mathrm{L}}, \nu_{\tau\mathrm{L}}$	electron neutrino, muon neutrino, tau neutrino field
Π	momentum density Section 3.3
ρ	electric charge density
$\rho(E)$	density of final states at energy E
Σ	spin operator acting on Dirac field Section 6.2
τ	mean life
$\tau,\ \tau_{\mathrm{L}}, \tau_{\mathrm{R}}$	tau Dirac, two-component left-handed, right-handed field
Φ	complex scalar field Section 3.7

ϕ	real scalar field Section 2.3, scalar potential Section 4.1, gauge parameter field Section 10.2
ϕ_0	vacuum expectation value of the Higgs field
χ	gauge parameter field Section 4.3, scalar field Section 10.3
ψ	four-component Dirac field
ψ_L, ψ_R	two-component left-handed, right-handed spinor field
$\bar{\psi}$	$\psi^{\dagger}\gamma^{o}$ Section 5.5
ω	frequency