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Nuclear and Particle Physics

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Contents

Symbols and Notation

A	mass number
A	axial vector
$A(t)$	activity (radioactivity)
B	binding energy; also baryon number
b	barn
$\mathfrak{B}$	bottomness
Bq	Becquerel
C	charge conjugation operator
c	speed of light
$\mathfrak{C}$	charm
d	electric dipole moment
E	energy
e	unit of charge
eV	electronvolt
$F(Z, E)$	Fermi function
G	gravitational constant
G_A	axial vector β-decay coupling constant
G_F	Fermi constant $(= G_\mu)$
G_V	polar vector β-decay coupling constant
G_β	β-decay coupling constant
G_μ	μ-decay coupling constant
g	g-factor; also weak interaction coupling constant
g_s	strong interaction coupling constant
H	Hamiltonian operator
h	Planck's constant
$\hbar$	$h/2\pi$
I	isospin (see below) of nucleus or particle; also moment of inertia

I_3	3-component of isospin
J	spin (see below) of nucleus or elementary particle
$J(\mathrm{ij})$	weak current involving particles i and j
j	total angular momentum quantum number of a nucleon
$\boldsymbol{L}$	orbital angular momentum operator
L_i	lepton number (i = e, μ, τ)
l	orbital angular momentum quantum number
M	atomic mass
m	z component of j
m_i	mass of particle i
m_l	z component of l
N	neutron number
N_A	Avogadro's number
n	radial quantum number
P	parity ($= \pm 1$); also probability
P	parity operator
p	momentum
Q	quadrupole moment; also Q value of a nuclear reaction; also electric charge of elementary particle
R	nuclear radius
S	strangeness; also separation energy
s_i	spin (see below) of nucleon (i = n, p) or quark (i = u, d, ...)
T	kinetic energy; also transition probability
t	time
$t_{1/2}$	half-life
$\mathfrak{T}$	topness
u	symbol for wave function
u	atomic mass unit
V	potential energy
V	polar vector
v	speed; also used as symbol for wave function
Y	hypercharge ($= B + S$)
$Y_{lm}(\theta\phi)$	spherical harmonic
Z	atomic number
α	fine structure constant (strength of electromagnetic interaction)
α_s	strength of strong interaction (cf. α)
Γ	width of resonance
ε	energy in units of $m_\mathrm{e}c^2$
ε_0	permittivity of vacuum
θ_C	Cabbibo angle

θ_W	weak mixing angle
λ	wavelength (usually de Broglie wavelength); also decay constant; also helicity
$\bar{\lambda}$	$\lambda/2\pi$
μ	magnetic moment; also reduced mass
μ_B	Bohr magneton
μ_N	nuclear magneton
ν	frequency
ρ	density (mass or charge)
σ	reaction cross-section
τ	mean life
ψ	wave function
Ω	solid angle
ω	angular frequency; also angular velocity

Note on spin and isospin. The notations used in nuclear physics and particle physics for spin and isospin tend to differ. Many books and publications use the following:

nuclear physics	
nuclear spin	I
nuclear isospin	T
particle physics	
particle spin	J
particle isospin	I

The confusion is obvious.

In this book, which covers both fields, the following notation will be used throughout:

nuclear spin	J (operator $\boldsymbol{J}$)
particle spin	J (operator $\boldsymbol{J}$)
nuclear isospin	I (operator $\boldsymbol{I}$)
particle isospin	I (operator $\boldsymbol{I}$)

One exception is that, when considering nuclear structure, the spins of the individual neutrons and protons will be denoted by s (operator $\boldsymbol{s}$). Similarly, when considering the quark structure of elementary particles the quark spins will be denoted by s (operator $\boldsymbol{s}$). In both cases appropriate suffices (e.g. n, p, u, d, ...) will be added.

Preface

This book is intended to give a clear and concise introductory account of the basic ideas underlying nuclear and elementary particle physics. The attempt throughout is to convey a sound physical understanding of the structures and processes encountered. It assumes some knowledge of elementary quantum mechanics, particularly the treatment of angular momentum, and the rudiments of special relativity. In addition to 'standard' calculations based on this knowledge, frequent use is made of 'order-of-magnitude' and 'dimensional' arguments. In this way it has been possible to give some discussion of quite advanced topics and recent developments. Although reference is made from time to time to the apparatus of nuclear and particle physics no technical detail is given. My basic hope is that students using this book will acquire a sound understanding of what nuclear and particle physics is about and will wish to learn more.

I am indebted to Dr David Bailin and various (nameless) referees for penetrating and helpful comments on parts of the text.

Roger Blin-Stoyle