Volume 667, Issues 1–5, 18 September 2008 ISSN 0370-2693

ELSEVIER

PHYSICS LETTERS B

REVIEW OF PARTICLE PHYSICS

July 2008

COMPLETE VOLUME

Available online at

ScienceDirect

www.sciencedirect.com

http://www.elsevier.com/locate/physletb

SUMMARY TABLES OF PARTICLE PROPERTIES

Extracted from the Particle Listings of the
Review of Particle Physics
C. Amsler *et al.*, PL **B667**, 1 (2008)
Available at `http://pdg.lbl.gov`

Particle Data Group

C. Amsler, M. Doser, M. Antonelli, D.M. Asner, K.S. Babu, H. Baer, H.R. Band, R.M. Barnett, E. Bergren, J. Beringer, G. Bernardi, W. Bertl, H. Bichsel, O. Biebel, P. Bloch, E. Blucher, S. Blusk, R.N. Cahn, M. Carena, C. Caso, A. Ceccucci, D. Chakraborty, M.-C. Chen, R.S. Chivukula, G. Cowan, O. Dahl, G. D'Ambrosio, T. Damour, A. de Gouvêa, T. DeGrand, B. Dobrescu, M. Drees, D.A. Edwards, S. Eidelman, V.D. Elvira, J. Erler, V.V. Ezhela, J.L. Feng, W. Fetscher, B.D. Fields, B. Foster, T.K. Gaisser, L. Garren, H.-J. Gerber, G. Gerbier, T. Gherghetta, G.F. Giudice, M. Goodman, C. Grab, A.V. Gritsan, J.-F. Grivaz, D.E. Groom, M. Grünewald, A. Gurtu, T. Gutsche, H.E. Haber, K. Hagiwara, C. Hagmann, K.G. Hayes, J.J. Hernández-Rey, K. Hikasa, I. Hinchliffe, A. Höcker, J. Huston, P. Igo-Kemenes, J.D. Jackson, K.F. Johnson, T. Junk, D. Karlen, B. Kayser, D. Kirkby, S.R. Klein, I.G. Knowles, C. Kolda, R.V. Kowalewski, P. Kreitz, B. Krusche, Yu.V. Kuyanov, Y. Kwon, O. Lahav, P. Langacker, A. Liddle, Z. Ligeti, C.-J. Lin, T.M. Liss, L. Littenberg, J.C. Liu, K.S. Lugovsky, S.B. Lugovsky, H. Mahlke, M.L. Mangano, T. Mannel, A.V. Manohar, W.J. Marciano, A.D. Martin, A. Masoni, D. Milstead, R. Miquel, K. Mönig, H. Murayama, K. Nakamura, M. Narain, P. Nason, S. Navas, P. Nevski, Y. Nir, K.A. Olive, L. Pape, C. Patrignani, J.A. Peacock, A. Piepke, G. Punzi, A. Quadt, S. Raby, G. Raffelt, B.N. Ratcliff, B. Renk, P. Richardson, S. Roesler, S. Rolli, A. Romaniouk, L.J. Rosenberg, J.L. Rosner, C.T. Sachrajda, Y. Sakai, S. Sarkar, F. Sauli, O. Schneider, D. Scott, W.G. Seligman, M.H. Shaevitz, T. Sjöstrand, J.G. Smith, G.F. Smoot, S. Spanier, H. Spieler, A. Stahl, T. Stanev, S.L. Stone, T. Sumiyoshi, M. Tanabashi, J. Terning, M. Titov, N.P. Tkachenko, N.A. Törnqvist, D. Tovey, G.H. Trilling, T.G. Trippe, G. Valencia, K. van Bibber, M.G. Vincter, P. Vogel, D.R. Ward, T. Watari, B.R. Webber, G. Weiglein, J.D. Wells, M. Whalley, A. Wheeler, C.G. Wohl, L. Wolfenstein, J. Womersley, C.L. Woody, R.L. Workman, A. Yamamoto, W.-M. Yao, O.V. Zenin, J. Zhang, R.-Y. Zhu, P.A. Zyla

Technical Associates:

G. Harper, V.S. Lugovsky, P. Schaffner

(Approximate closing date for data: January 15, 2008)

GAUGE AND HIGGS BOSONS

γ

$I(J^{PC}) = 0,1(1\,-\,-)$

Mass $m < 1 \times 10^{-18}$ eV
Charge $q < 5 \times 10^{-30}$ e
Mean life τ = Stable

g or gluon

$I(J^{P}) = 0(1^{-})$

Mass $m = 0$ [a]
SU(3) color octet

W

$J = 1$

Charge = $\pm 1\ e$
Mass $m = 80.398 \pm 0.025$ GeV
$m_Z - m_W = 10.4 \pm 1.6$ GeV
$m_{W^+} - m_{W^-} = -0.2 \pm 0.6$ GeV
Full width $\Gamma = 2.141 \pm 0.041$ GeV
$\langle N_{\pi^\pm} \rangle = 15.70 \pm 0.35$
$\langle N_{K^\pm} \rangle = 2.20 \pm 0.19$
$\langle N_p \rangle = 0.92 \pm 0.14$
$\langle N_{\text{charged}} \rangle = 19.39 \pm 0.08$

W^- modes are charge conjugates of the modes below.

W^+ DECAY MODES		Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$\ell^+\nu$	[b]	(10.80 ± 0.09) %		–
$e^+\nu$		(10.75 ± 0.13) %		40199
$\mu^+\nu$		(10.57 ± 0.15) %		40199
$\tau^+\nu$		(11.25 ± 0.20) %		40179
hadrons		(67.60 ± 0.27) %		–
$\pi^+\gamma$		$< 8 \times 10^{-5}$	95%	40199
$D_s^+\gamma$		$< 1.3 \times 10^{-3}$	95%	40175
cX		(33.4 ± 2.6) %		–
$c\bar{s}$		$(31\ {}^{+13}_{-11})$ %		–
invisible	[c]	(1.4 ± 2.8) %		–

Z

$J = 1$

Charge = 0
Mass $m = 91.1876 \pm 0.0021$ GeV [d]
Full width $\Gamma = 2.4952 \pm 0.0023$ GeV
$\Gamma(\ell^+\ell^-) = 83.984 \pm 0.086$ MeV [b]
$\Gamma(\text{invisible}) = 499.0 \pm 1.5$ MeV [e]
$\Gamma(\text{hadrons}) = 1744.4 \pm 2.0$ MeV
$\Gamma(\mu^+\mu^-)/\Gamma(e^+e^-) = 1.0009 \pm 0.0028$
$\Gamma(\tau^+\tau^-)/\Gamma(e^+e^-) = 1.0019 \pm 0.0032$ [f]

Average charged multiplicity

$\langle N_{charged} \rangle = 20.76 \pm 0.16$ (S = 2.1)

Couplings to leptons

$g_V^{\ell} = -0.03783 \pm 0.00041$
$g_A^{\ell} = -0.50123 \pm 0.00026$
$g^{\nu_\ell} = 0.5008 \pm 0.0008$
$g^{\nu_e} = 0.53 \pm 0.09$
$g^{\nu_\mu} = 0.502 \pm 0.017$

Asymmetry parameters [g]

$A_e = 0.1515 \pm 0.0019$
$A_\mu = 0.142 \pm 0.015$
$A_\tau = 0.143 \pm 0.004$
$A_s = 0.90 \pm 0.09$
$A_c = 0.670 \pm 0.027$
$A_b = 0.923 \pm 0.020$

Charge asymmetry (%) at Z pole

$A_{FB}^{(0\ell)} = 1.71 \pm 0.10$
$A_{FB}^{(0u)} = 4 \pm 7$
$A_{FB}^{(0s)} = 9.8 \pm 1.1$
$A_{FB}^{(0c)} = 7.07 \pm 0.35$
$A_{FB}^{(0b)} = 9.92 \pm 0.16$

QUARKS

The u-, d-, and s-quark masses are estimates of so-called "current-quark masses," in a mass-independent subtraction scheme such as $\overline{\text{MS}}$ at a scale $\mu \approx 2$ GeV. The c- and b-quark masses are the "running" masses in the $\overline{\text{MS}}$ scheme. For the b-quark we also quote the 1S mass. These can be different from the heavy quark masses obtained in potential models.

u

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

Mass $m = 1.5$ to 3.3 MeV [a] Charge $= \frac{2}{3}\ e$ $I_z = +\frac{1}{2}$
$m_u/m_d = 0.35$ to 0.60

d

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

Mass $m = 3.5$ to 6.0 MeV [a] Charge $= -\frac{1}{3}\ e$ $I_z = -\frac{1}{2}$
$m_s/m_d = 17$ to 22
$\overline{m} = (m_u+m_d)/2 = 2.5$ to 5.0 MeV

s

$I(J^P) = 0(\frac{1}{2}^+)$

Mass $m = 104^{+26}_{-34}$ MeV [a] Charge $= -\frac{1}{3}\ e$ Strangeness $= -1$
$(m_s - (m_u + m_d)/2)/(m_d - m_u) = 30$ to 50

c

$I(J^P) = 0(\frac{1}{2}^+)$

Mass $m = 1.27^{+0.07}_{-0.11}$ GeV Charge $= \frac{2}{3}\ e$ Charm $= +1$

b

$I(J^P) = 0(\frac{1}{2}^+)$

Charge $= -\frac{1}{3}\ e$ Bottom $= -1$

Mass $m = 4.20^{+0.17}_{-0.07}$ GeV ($\overline{\text{MS}}$ mass)

t

$I(J^P) = 0(\frac{1}{2}^+)$

Charge $= \frac{2}{3}\ e$ Top $= +1$

Mass $m = 171.2 \pm 2.1$ GeV [b] (direct observation of top events)

t DECAY MODES		Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$W q(q = b, s, d)$				–
$W b$				–
$\ell \nu_\ell$anything		[c,d] (9.4±2.4) %		–
$\gamma q(q=u,c)$		[e] < 5.9 $\times 10^{-3}$	95%	–
$\Delta T = 1$ weak neutral current ($T1$) modes				
$Z q(q=u,c)$	$T1$	[f] < 13.7 %	95%	–

b' (4^{th} Generation) Quark, Searches for

Mass $m >$ 190 GeV, CL = 95% ($p\overline{p}$, quasi-stable b')
Mass $m >$ 199 GeV, CL = 95% ($p\overline{p}$, neutral-current decays)
Mass $m >$ 128 GeV, CL = 95% ($p\overline{p}$, charged-current decays)
Mass $m >$ 46.0 GeV, CL = 95% (e^+e^-, all decays)

t' (4^{th} Generation) Quark, Searches for

Mass $m >$ 256 GeV, CL = 95% ($p\overline{p}$, $t'\overline{t}'$ prod., $t' \to Wq$)

Free Quark Searches

All searches since 1977 have had negative results.

NOTES

[a] The ratios m_u/m_d and m_s/m_d are extracted from pion and kaon masses using chiral symmetry. The estimates of u and d masses are not without controversy and remain under active investigation. Within the literature there are even suggestions that the u quark could be essentially massless. The s-quark mass is estimated from SU(3) splittings in hadron masses.

[b] Based on published top mass measurements using data from Tevatron Run-I and Run-II. Including also the most recent unpublished results from Run-II, the Tevatron Electroweak Working Group reports a top mass of $172.6 \pm 0.8 \pm 1.1$ GeV. See the note "The Top Quark" in the Quark Particle Listings of this *Review*.

[c] ℓ means e or μ decay mode, not the sum over them.

[d] Assumes lepton universality and W-decay acceptance.

[e] This limit is for $\Gamma(t \to \gamma q)/\Gamma(t \to Wb)$.

[f] This limit is for $\Gamma(t \to Zq)/\Gamma(t \to Wb)$.

LIGHT UNFLAVORED MESONS ($S = C = B = 0$)

For $I = 1$ (π, b, ρ, a): $u\bar{d}$, $(u\bar{u}-d\bar{d})/\sqrt{2}$, $d\bar{u}$;
for $I = 0$ (η, η', h, h', ω, ϕ, f, f'): $c_1(u\bar{u}+d\bar{d}) + c_2(s\bar{s})$

$\pi^{\pm}$

$I^G(J^P) = 1^-(0^-)$

Mass $m = 139.57018 \pm 0.00035$ MeV (S = 1.2)
Mean life $\tau = (2.6033 \pm 0.0005) \times 10^{-8}$ s (S = 1.2)
$c\tau = 7.8045$ m

$\pi^{\pm} \to \ell^{\pm}\nu\gamma$ form factors [a]

$F_V = 0.017 \pm 0.008$
$F_A = 0.0115 \pm 0.0005$ (S = 1.2)
$R = 0.059^{+0.009}_{-0.008}$

π^- modes are charge conjugates of the modes below.

For decay limits to particles which are not established, see the appropriate Search sections (Massive Neutrino Peak Search Test, A^0 (axion), and Other Light Boson (X^0) Searches, etc.).

π^+ DECAY MODES		Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$\mu^+\nu_\mu$	[b]	(99.98770 ± 0.00004) %		30
$\mu^+\nu_\mu\gamma$	[c]	$(2.00 \pm 0.25) \times 10^{-4}$		30
$e^+\nu_e$	[b]	$(1.230 \pm 0.004) \times 10^{-4}$		70
$e^+\nu_e\gamma$	[c]	$(1.61 \pm 0.23) \times 10^{-7}$		70
$e^+\nu_e\pi^0$		$(1.036 \pm 0.006) \times 10^{-8}$		4
$e^+\nu_e e^+ e^-$		$(3.2 \pm 0.5) \times 10^{-9}$		70
$e^+\nu_e\nu\bar{\nu}$		$< 5 \times 10^{-6}$	90%	70
Lepton Family number (*LF*) or Lepton number (*L*) violating modes				
$\mu^+\bar{\nu}_e$	*L* [d]	$< 1.5 \times 10^{-3}$	90%	30
$\mu^+\nu_e$	*LF* [d]	$< 8.0 \times 10^{-3}$	90%	30
$\mu^- e^+ e^+ \nu$	*LF*	$< 1.6 \times 10^{-6}$	90%	30

π^0

$I^G(J^{PC}) = 1^-(0^{-+})$

Mass $m = 134.9766 \pm 0.0006$ MeV (S = 1.1)
$m_{\pi^{\pm}} - m_{\pi^0} = 4.5936 \pm 0.0005$ MeV
Mean life $\tau = (8.4 \pm 0.6) \times 10^{-17}$ s (S = 3.0)
$c\tau = 25.1$ nm

For decay limits to particles which are not established, see the appropriate Search sections (A^0 (axion) and Other Light Boson (X^0) Searches, etc.).

π^0 DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
2γ		(98.798 ± 0.032) %	S=1.1	67
$e^+e^-\gamma$		(1.198 ± 0.032) %	S=1.1	67
γ positronium		$(1.82 \pm 0.29) \times 10^{-9}$		67
$e^+e^+e^-e^-$		$(3.14 \pm 0.30) \times 10^{-5}$		67
e^+e^-		$(6.46 \pm 0.33) \times 10^{-8}$		67
4γ		$< 2 \times 10^{-8}$	CL=90%	67
$\nu\bar{\nu}$	[e]	$< 2.7 \times 10^{-7}$	CL=90%	67
$\nu_e\bar{\nu}_e$		$< 1.7 \times 10^{-6}$	CL=90%	67
$\nu_\mu\bar{\nu}_\mu$		$< 1.6 \times 10^{-6}$	CL=90%	67
$\nu_\tau\bar{\nu}_\tau$		$< 2.1 \times 10^{-6}$	CL=90%	67
$\gamma\nu\bar{\nu}$		$< 6 \times 10^{-4}$	CL=90%	67
Charge conjugation (*C*) or Lepton Family number (*LF*) violating modes				
3γ	*C*	$< 3.1 \times 10^{-8}$	CL=90%	67
μ^+e^-	*LF*	$< 3.8 \times 10^{-10}$	CL=90%	26
μ^-e^+	*LF*	$< 3.4 \times 10^{-9}$	CL=90%	26
$\mu^+e^- + \mu^-e^+$	*LF*	$< 1.72 \times 10^{-8}$	CL=90%	26

η

$I^G(J^{PC}) = 0^+(0^{-+})$

Mass $m = 547.853 \pm 0.024$ MeV [f]
Full width $\Gamma = 1.30 \pm 0.07$ keV [g]

C-nonconserving decay parameters

$\pi^+\pi^-\pi^0$ Left-right asymmetry $= (0.09 \pm 0.17) \times 10^{-2}$
$\pi^+\pi^-\pi^0$ Sextant asymmetry $= (0.18 \pm 0.16) \times 10^{-2}$
$\pi^+\pi^-\pi^0$ Quadrant asymmetry $= (-0.17 \pm 0.17) \times 10^{-2}$
$\pi^+\pi^-\gamma$ Left-right asymmetry $= (0.9 \pm 0.4) \times 10^{-2}$
$\pi^+\pi^-\gamma$ β (D-wave) $= -0.02 \pm 0.07$ (S = 1.3)

Dalitz plot parameter

$\pi^0\pi^0\pi^0$ $\alpha = -0.031 \pm 0.004$

η DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Neutral modes				
neutral modes		(71.91 ± 0.34) %	S=1.2	–
2γ	[g]	(39.31 ± 0.20) %	S=1.1	274
$3\pi^0$		(32.56 ± 0.23) %	S=1.1	179
$\pi^0 2\gamma$		$(4.4 \pm 1.5) \times 10^{-4}$	S=2.0	257
$\pi^0\pi^0\gamma\gamma$		$< 1.2 \times 10^{-3}$	CL=90%	238
4γ		$< 2.8 \times 10^{-4}$	CL=90%	274
invisible		$< 6 \times 10^{-4}$	CL=90%	–
Charged modes				
charged modes		(28.06 ± 0.34) %	S=1.2	–
$\pi^+\pi^-\pi^0$		(22.73 ± 0.28) %	S=1.2	174
$\pi^+\pi^-\gamma$		(4.60 ± 0.16) %	S=2.1	236
$e^+e^-\gamma$		$(6.8 \pm 0.8) \times 10^{-3}$	S=1.7	274
$\mu^+\mu^-\gamma$		$(3.1 \pm 0.4) \times 10^{-4}$		253
e^+e^-		$< 7.7 \times 10^{-5}$	CL=90%	274
$\mu^+\mu^-$		$(5.8 \pm 0.8) \times 10^{-6}$		253
$e^+e^-e^+e^-$		$< 6.9 \times 10^{-5}$	CL=90%	274
$\pi^+\pi^-e^+e^-$		$(4.2 \pm 1.2) \times 10^{-4}$		235
$\pi^+\pi^-2\gamma$		$< 2.0 \times 10^{-3}$		236
$\pi^+\pi^-\pi^0\gamma$		$< 5 \times 10^{-4}$	CL=90%	174
$\pi^0\mu^+\mu^-\gamma$		$< 3 \times 10^{-6}$	CL=90%	210
Charge conjugation (*C*), Parity (*P*), Charge conjugation × Parity (*CP*), or Lepton Family number (*LF*) violating modes				
$\pi^0\gamma$	*C*	$< 9 \times 10^{-5}$	CL=90%	257
$\pi^+\pi^-$	*P,CP*	$< 1.3 \times 10^{-5}$	CL=90%	236
$\pi^0\pi^0$	*P,CP*	$< 3.5 \times 10^{-4}$	CL=90%	238
$\pi^0\pi^0\gamma$	*C*	$< 5 \times 10^{-4}$	CL=90%	238
$\pi^0\pi^0\pi^0\gamma$	*C*	$< 6 \times 10^{-5}$	CL=90%	179
3γ	*C*	$< 1.6 \times 10^{-5}$	CL=90%	274
$4\pi^0$	*P,CP*	$< 6.9 \times 10^{-7}$	CL=90%	40
$\pi^0e^+e^-$	*C* [h]	$< 4 \times 10^{-5}$	CL=90%	257
$\pi^0\mu^+\mu^-$	*C* [h]	$< 5 \times 10^{-6}$	CL=90%	210
$\mu^+e^- + \mu^-e^+$	*LF*	$< 6 \times 10^{-6}$	CL=90%	264

$f_0(600)$ [i] or σ

$I^G(J^{PC}) = 0^+(0^{++})$

Mass $m = (400\text{–}1200)$ MeV
Full width $\Gamma = (600\text{–}1000)$ MeV

$f_0(600)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\pi\pi$	dominant	–
$\gamma\gamma$	seen	–

N BARYONS
$(S = 0, I = 1/2)$

$p, N^+ = uud$; $n, N^0 = udd$

p

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

Mass $m = 1.00727646688 \pm 0.00000000013$ u
Mass $m = 938.27203 \pm 0.00008$ MeV [a]
$|m_p - m_{\overline{p}}|/m_p < 2 \times 10^{-9}$, CL = 90% [b]
$|\frac{q_{\overline{p}}}{m_{\overline{p}}}|/(\frac{q_p}{m_p}) = 0.99999999991 \pm 0.00000000009$
$|q_p + q_{\overline{p}}|/e < 2 \times 10^{-9}$, CL = 90% [b]
$|q_p + q_e|/e < 1.0 \times 10^{-21}$ [c]
Magnetic moment $\mu = 2.792847351 \pm 0.000000028\ \mu_N$
$(\mu_p + \mu_{\overline{p}}) / \mu_p = (-2.6 \pm 2.9) \times 10^{-3}$
Electric dipole moment $d < 0.54 \times 10^{-23}$ $e$cm
Electric polarizability $\alpha = (12.0 \pm 0.6) \times 10^{-4}$ fm^3
Magnetic polarizability $\beta = (1.9 \pm 0.5) \times 10^{-4}$ fm^3
Charge radius = 0.875 ± 0.007 fm
Mean life $\tau > 2.1 \times 10^{29}$ years, CL = 90% ($p \to$ invisible mode)
Mean life $\tau > 10^{31}$ to 10^{33} years [d] (mode dependent)

See the "Note on Nucleon Decay" in our 1994 edition (Phys. Rev. **D50**, 1173) for a short review.

The "partial mean life" limits tabulated here are the limits on τ/B_i, where τ is the total mean life and B_i is the branching fraction for the mode in question. For N decays, p and n indicate proton and neutron partial lifetimes.

p DECAY MODES	Partial mean life (10^{30} years)	Confidence level	p (MeV/c)
Antilepton + meson			
$N \to e^+\pi$	> 158 (n), > 1600 (p)	90%	459
$N \to \mu^+\pi$	> 100 (n), > 473 (p)	90%	453
$N \to \nu\pi$	> 112 (n), > 25 (p)	90%	459
$p \to e^+\eta$	> 313	90%	309
$p \to \mu^+\eta$	> 126	90%	297
$n \to \nu\eta$	> 158	90%	310
$N \to e^+\rho$	> 217 (n), > 75 (p)	90%	149
$N \to \mu^+\rho$	> 228 (n), > 110 (p)	90%	113
$N \to \nu\rho$	> 19 (n), > 162 (p)	90%	149
$p \to e^+\omega$	> 107	90%	143
$p \to \mu^+\omega$	> 117	90%	105
$n \to \nu\omega$	> 108	90%	144
$N \to e^+K$	> 17 (n), > 150 (p)	90%	339
$p \to e^+K^0_S$	> 120	90%	337
$p \to e^+K^0_L$	> 51	90%	337
$N \to \mu^+K$	> 26 (n), > 120 (p)	90%	329
$p \to \mu^+K^0_S$	> 150	90%	326
$p \to \mu^+K^0_L$	> 83	90%	326
$N \to \nu K$	> 86 (n), > 670 (p)	90%	339
$n \to \nu K^0_S$	> 51	90%	338
$p \to e^+K^*(892)^0$	> 84	90%	45
$N \to \nu K^*(892)$	> 78 (n), > 51 (p)	90%	45
Antilepton + mesons			
$p \to e^+\pi^+\pi^-$	> 82	90%	448
$p \to e^+\pi^0\pi^0$	> 147	90%	449
$n \to e^+\pi^-\pi^0$	> 52	90%	449
$p \to \mu^+\pi^+\pi^-$	> 133	90%	425
$p \to \mu^+\pi^0\pi^0$	> 101	90%	427
$n \to \mu^+\pi^-\pi^0$	> 74	90%	427
$n \to e^+K^0\pi^-$	> 18	90%	319
Lepton + meson			
$n \to e^-\pi^+$	> 65	90%	459
$n \to \mu^-\pi^+$	> 49	90%	453
$n \to e^-\rho^+$	> 62	90%	150
$n \to \mu^-\rho^+$	> 7	90%	114
$n \to e^-K^+$	> 32	90%	340
$n \to \mu^-K^+$	> 57	90%	330
Lepton + mesons			
$p \to e^-\pi^+\pi^+$	> 30	90%	448
$n \to e^-\pi^+\pi^0$	> 29	90%	449
$p \to \mu^-\pi^+\pi^+$	> 17	90%	425
$n \to \mu^-\pi^+\pi^0$	> 34	90%	427
$p \to e^-\pi^+K^+$	> 75	90%	320
$p \to \mu^-\pi^+K^+$	> 245	90%	279
Antilepton + photon(s)			
$p \to e^+\gamma$	> 670	90%	469
$p \to \mu^+\gamma$	> 478	90%	463
$n \to \nu\gamma$	> 28	90%	470
$p \to e^+\gamma\gamma$	> 100	90%	469
$n \to \nu\gamma\gamma$	> 219	90%	470
Three (or more) leptons			
$p \to e^+e^+e^-$	> 793	90%	469
$p \to e^+\mu^+\mu^-$	> 359	90%	457
$p \to e^+\nu\nu$	> 17	90%	469
$n \to e^+e^-\nu$	> 257	90%	470
$n \to \mu^+e^-\nu$	> 83	90%	464
$n \to \mu^+\mu^-\nu$	> 79	90%	458
$p \to \mu^+e^+e^-$	> 529	90%	463
$p \to \mu^+\mu^+\mu^-$	> 675	90%	439
$p \to \mu^+\nu\nu$	> 21	90%	463
$p \to e^-\mu^+\mu^+$	> 6	90%	457
$n \to 3\nu$	> 0.0005	90%	470
Inclusive modes			
$N \to e^+$anything	> 0.6 (n, p)	90%	–
$N \to \mu^+$anything	> 12 (n, p)	90%	–
$N \to e^+\pi^0$anything	> 0.6 (n, p)	90%	–
$\Delta B = 2$ dinucleon modes			
The following are lifetime limits per iron nucleus.			
$pp \to \pi^+\pi^+$	> 0.7	90%	–
$pn \to \pi^+\pi^0$	> 2	90%	–
$nn \to \pi^+\pi^-$	> 0.7	90%	–
$nn \to \pi^0\pi^0$	> 3.4	90%	–
$pp \to e^+e^+$	> 5.8	90%	–
$pp \to e^+\mu^+$	> 3.6	90%	–
$pp \to \mu^+\mu^+$	> 1.7	90%	–
$pn \to e^+\overline{\nu}$	> 2.8	90%	–
$pn \to \mu^+\overline{\nu}$	> 1.6	90%	–
$nn \to \nu_e\overline{\nu}_e$	> 0.000049	90%	–
$pn \to$ invisible	$>2.1 \times 10^{-5}$	90%	–
$pp \to$ invisible	> 0.00005	90%	–

$\overline{p}$ DECAY MODES

$\overline{p}$ DECAY MODES	Partial mean life (years)	Confidence level	p (MeV/c)
$\overline{p} \to e^-\gamma$	$> 7 \times 10^5$	90%	469
$\overline{p} \to \mu^-\gamma$	$> 5 \times 10^4$	90%	463
$\overline{p} \to e^-\pi^0$	$> 4 \times 10^5$	90%	459
$\overline{p} \to \mu^-\pi^0$	$> 5 \times 10^4$	90%	453
$\overline{p} \to e^-\eta$	$> 2 \times 10^4$	90%	309
$\overline{p} \to \mu^-\eta$	$> 8 \times 10^3$	90%	297
$\overline{p} \to e^-K^0_S$	> 900	90%	337
$\overline{p} \to \mu^-K^0_S$	$> 4 \times 10^3$	90%	326
$\overline{p} \to e^-K^0_L$	$> 9 \times 10^3$	90%	337
$\overline{p} \to \mu^-K^0_L$	$> 7 \times 10^3$	90%	326
$\overline{p} \to e^-\gamma\gamma$	$> 2 \times 10^4$	90%	469
$\overline{p} \to \mu^-\gamma\gamma$	$> 2 \times 10^4$	90%	463
$\overline{p} \to e^-\omega$	> 200	90%	143

LEPTONS

e

$J = \frac{1}{2}$

Mass $m = (548.57990943 \pm 0.00000023) \times 10^{-6}$ u
Mass $m = 0.510998910 \pm 0.000000013$ MeV
$|m_{e^+} - m_{e^-}|/m < 8 \times 10^{-9}$, CL = 90%
$|q_{e^+} + q_{e^-}|/e < 4 \times 10^{-8}$
Magnetic moment anomaly
$(g-2)/2 = (1159.6521811 \pm 0.0000007) \times 10^{-6}$
$(g_{e^+} - g_{e^-}) / g_{\text{average}} = (-0.5 \pm 2.1) \times 10^{-12}$
Electric dipole moment $d = (0.07 \pm 0.07) \times 10^{-26}$ $e$cm
Mean life $\tau > 4.6 \times 10^{26}$ yr, CL = 90% [a]

μ

$J = \frac{1}{2}$

Mass $m = 0.1134289256 \pm 0.0000000029$ u
Mass $m = 105.658367 \pm 0.000004$ MeV
Mean life $\tau = (2.197019 \pm 0.000021) \times 10^{-6}$ s (S = 1.1)
$\tau_{\mu^+}/\tau_{\mu^-} = 1.00002 \pm 0.00008$
$c\tau = 658.650$ m
Magnetic moment anomaly $(g-2)/2 = (11659208 \pm 6) \times 10^{-10}$
$(g_{\mu^+} - g_{\mu^-}) / g_{\text{average}} = (-0.11 \pm 0.12) \times 10^{-8}$
Electric dipole moment $d = (3.7 \pm 3.4) \times 10^{-19}$ $e$cm

Decay parameters [b]

$\rho = 0.7509 \pm 0.0010$
$\eta = 0.001 \pm 0.024$ (S = 2.0)
$\delta = 0.7495 \pm 0.0012$
$\xi P_\mu = 1.0007 \pm 0.0035$ [c]
$\xi P_\mu \delta/\rho > 0.99682$, CL = 90% [c]
$\xi' = 1.00 \pm 0.04$
$\xi'' = 0.7 \pm 0.4$
$\alpha/A = (0 \pm 4) \times 10^{-3}$
$\alpha'/A = (0 \pm 4) \times 10^{-3}$
$\beta/A = (4 \pm 6) \times 10^{-3}$
$\beta'/A = (1 \pm 5) \times 10^{-3}$
$\overline{\eta} = 0.02 \pm 0.08$

μ^+ modes are charge conjugates of the modes below.

μ^- DECAY MODES			Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$e^- \overline{\nu}_e \nu_\mu$			$\approx 100\%$		53
$e^- \overline{\nu}_e \nu_\mu \gamma$		[d]	(1.4 ± 0.4) %		53
$e^- \overline{\nu}_e \nu_\mu e^+ e^-$		[e]	$(3.4 \pm 0.4) \times 10^{-5}$		53
Lepton Family number (*LF*) violating modes					
$e^- \nu_e \overline{\nu}_\mu$	*LF*	[f]	< 1.2 %	90%	53
$e^- \gamma$	*LF*		$< 1.2 \times 10^{-11}$	90%	53
$e^- e^+ e^-$	*LF*		$< 1.0 \times 10^{-12}$	90%	53
$e^- 2\gamma$	*LF*		$< 7.2 \times 10^{-11}$	90%	53

τ

$J = \frac{1}{2}$

Mass $m = 1776.84 \pm 0.17$ MeV
$(m_{\tau^+} - m_{\tau^-})/m_{\text{average}} < 2.8 \times 10^{-4}$, CL = 90%
Mean life $\tau = (290.6 \pm 1.0) \times 10^{-15}$ s
$c\tau = 87.11$ μm
Magnetic moment anomaly > -0.052 and < 0.013, CL = 95%
$\text{Re}(d_\tau) = -0.22$ to 0.45×10^{-16} $e$cm, CL = 95%
$\text{Im}(d_\tau) = -0.25$ to 0.008×10^{-16} $e$cm, CL = 95%

Weak dipole moment

$\text{Re}(d^w_\tau) < 0.50 \times 10^{-17}$ $e$cm, CL = 95%
$\text{Im}(d^w_\tau) < 1.1 \times 10^{-17}$ $e$cm, CL = 95%

Weak anomalous magnetic dipole moment

$\text{Re}(\alpha^w_\tau) < 1.1 \times 10^{-3}$, CL = 95%
$\text{Im}(\alpha^w_\tau) < 2.7 \times 10^{-3}$, CL = 95%

Decay parameters

See the τ Particle Listings for a note concerning τ-decay parameters.

$\rho(e \text{ or } \mu) = 0.745 \pm 0.008$
$\rho(e) = 0.747 \pm 0.010$
$\rho(\mu) = 0.763 \pm 0.020$
$\xi(e \text{ or } \mu) = 0.985 \pm 0.030$
$\xi(e) = 0.994 \pm 0.040$
$\xi(\mu) = 1.030 \pm 0.059$
$\eta(e \text{ or } \mu) = 0.013 \pm 0.020$
$\eta(\mu) = 0.094 \pm 0.073$
$(\delta\xi)(e \text{ or } \mu) = 0.746 \pm 0.021$
$(\delta\xi)(e) = 0.734 \pm 0.028$
$(\delta\xi)(\mu) = 0.778 \pm 0.037$
$\xi(\pi) = 0.993 \pm 0.022$
$\xi(\rho) = 0.994 \pm 0.008$
$\xi(a_1) = 1.001 \pm 0.027$
$\xi(\text{all hadronic modes}) = 0.995 \pm 0.007$

τ^+ modes are charge conjugates of the modes below. "$h^\pm$" stands for $\pi^\pm$ or $K^\pm$. "ℓ" stands for e or μ. "Neutrals" stands for γ's and/or π^0's.

τ^- DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Modes with one charged particle				
particle$^- \geq 0$ neutrals $\geq 0K^0 \nu_\tau$ ("1-prong")		(85.36 ± 0.08) %	S=1.3	–
particle$^- \geq 0$ neutrals $\geq 0K^0_L \nu_\tau$		(84.73 ± 0.08) %	S=1.4	–
$\mu^- \overline{\nu}_\mu \nu_\tau$	[g]	(17.36 ± 0.05) %		885
$\mu^- \overline{\nu}_\mu \nu_\tau \gamma$	[e]	$(3.6 \pm 0.4) \times 10^{-3}$		885
$e^- \overline{\nu}_e \nu_\tau$	[g]	(17.85 ± 0.05) %		888
$e^- \overline{\nu}_e \nu_\tau \gamma$	[e]	(1.75 ± 0.18) %		888
$h^- \geq 0K^0_L \nu_\tau$		(12.13 ± 0.07) %	S=1.1	883
$h^- \nu_\tau$		(11.60 ± 0.06) %	S=1.1	883
$\pi^- \nu_\tau$	[g]	(10.91 ± 0.07) %	S=1.1	883
$K^- \nu_\tau$	[g]	$(6.95 \pm 0.23) \times 10^{-3}$	S=1.1	820
$h^- \geq 1$ neutrals ν_τ		(37.08 ± 0.11) %	S=1.2	–
$h^- \geq 1\pi^0 \nu_\tau (\text{ex.}K^0)$		(36.54 ± 0.11) %	S=1.2	–
$h^- \pi^0 \nu_\tau$		(25.95 ± 0.10) %	S=1.1	878
$\pi^- \pi^0 \nu_\tau$	[g]	(25.52 ± 0.10) %	S=1.1	878
$\pi^- \pi^0$ non-$\rho(770) \nu_\tau$		$(3.0 \pm 3.2) \times 10^{-3}$		878
$K^- \pi^0 \nu_\tau$	[g]	$(4.28 \pm 0.15) \times 10^{-3}$		814
$h^- \geq 2\pi^0 \nu_\tau$		(10.84 ± 0.12) %	S=1.3	–
$h^- 2\pi^0 \nu_\tau$		(9.49 ± 0.11) %	S=1.2	862
$h^- 2\pi^0 \nu_\tau (\text{ex.}K^0)$		(9.33 ± 0.12) %	S=1.2	862
$\pi^- 2\pi^0 \nu_\tau (\text{ex.}K^0)$	[g]	(9.27 ± 0.12) %	S=1.2	862
$\pi^- 2\pi^0 \nu_\tau (\text{ex.}K^0)$, scalar		$< 9 \times 10^{-3}$	CL=95%	862
$\pi^- 2\pi^0 \nu_\tau (\text{ex.}K^0)$, vector		$< 7 \times 10^{-3}$	CL=95%	862
$K^- 2\pi^0 \nu_\tau (\text{ex.}K^0)$	[g]	$(6.3 \pm 2.3) \times 10^{-4}$		796
$h^- \geq 3\pi^0 \nu_\tau$		(1.35 ± 0.07) %	S=1.1	–
$h^- \geq 3\pi^0 \nu_\tau (\text{ex. } K^0)$		(1.26 ± 0.07) %	S=1.1	–
$h^- 3\pi^0 \nu_\tau$		(1.18 ± 0.08) %		836
$\pi^- 3\pi^0 \nu_\tau (\text{ex.}K^0)$	[g]	(1.04 ± 0.07) %		836
$K^- 3\pi^0 \nu_\tau (\text{ex.}K^0, \eta)$	[g]	$(4.7 \pm 2.1) \times 10^{-4}$		765
$h^- 4\pi^0 \nu_\tau (\text{ex.}K^0)$		$(1.6 \pm 0.4) \times 10^{-3}$		800
$h^- 4\pi^0 \nu_\tau (\text{ex.}K^0, \eta)$	[g]	$(1.0 \pm 0.4) \times 10^{-3}$		800
$K^- \geq 0\pi^0 \geq 0K^0 \geq 0\gamma\ \nu_\tau$		(1.57 ± 0.04) %	S=1.1	820
$K^- \geq 1\ (\pi^0 \text{ or } K^0 \text{ or } \gamma)\ \nu_\tau$		$(8.74 \pm 0.32) \times 10^{-3}$		–
Modes with K^0's				
K^0_S(particles)$^- \nu_\tau$		$(9.2 \pm 0.4) \times 10^{-3}$	S=1.4	–
$h^- \overline{K}^0 \nu_\tau$		$(10.0 \pm 0.5) \times 10^{-3}$	S=1.8	812
$\pi^- \overline{K}^0 \nu_\tau$	[g]	$(8.4 \pm 0.4) \times 10^{-3}$	S=2.0	812
$\pi^- \overline{K}^0$ (non-$K^*(892)^-$)ν_τ		$(5.4 \pm 2.1) \times 10^{-4}$		812
$K^- K^0 \nu_\tau$	[g]	$(1.58 \pm 0.16) \times 10^{-3}$		737
$K^- K^0 \geq 0\pi^0 \nu_\tau$		$(3.16 \pm 0.23) \times 10^{-3}$		737
$h^- \overline{K}^0 \pi^0 \nu_\tau$		$(5.5 \pm 0.4) \times 10^{-3}$		794
$\pi^- \overline{K}^0 \pi^0 \nu_\tau$	[g]	$(3.9 \pm 0.4) \times 10^{-3}$		794
$\overline{K}^0 \rho^- \nu_\tau$		$(2.2 \pm 0.5) \times 10^{-3}$		612
$K^- K^0 \pi^0 \nu_\tau$	[g]	$(1.58 \pm 0.20) \times 10^{-3}$		685

1. PHYSICAL CONSTANTS

Table 1.1. Reviewed 2007 by P.J. Mohr and B.N. Taylor (NIST). Based mainly on the "CODATA Recommended Values of the Fundamental Physical Constants: 2006" by P.J. Mohr, B.N. Taylor, and D.B. Newell (to be published in Rev. Mod. Phys, and J. Phys. Chem. Ref. Data). The last group of constants (beginning with the Fermi coupling constant) comes from the Particle Data Group. The figures in parentheses after the values give the 1-standard-deviation uncertainties in the last digits; the corresponding fractional uncertainties in parts per 10^9 (ppb) are given in the last column. This set of constants (aside from the last group) is recommended for international use by CODATA (the Committee on Data for Science and Technology). The full 2006 CODATA set of constants may be found at `http://physics.nist.gov/constants`.

Quantity	Symbol, equation	Value	Uncertainty (ppb)
speed of light in vacuum	c	$299\ 792\ 458$ m s^{-1}	exact*
Planck constant	h	$6.626\ 068\ 96(33)\times10^{-34}$ J s	50
Planck constant, reduced	$\hbar \equiv h/2\pi$	$1.054\ 571\ 628(53)\times10^{-34}$ J s	50
		$= 6.582\ 118\ 99(16)\times10^{-22}$ MeV s	25
electron charge magnitude	e	$1.602\ 176\ 487(40)\times10^{-19}$ C $= 4.803\ 204\ 27(12)\times10^{-10}$ esu	25, 25
conversion constant	$\hbar c$	$197.326\ 9631(49)$ MeV fm	25
conversion constant	$(\hbar c)^2$	$0.389\ 379\ 304(19)$ GeV^2 mbarn	50
electron mass	m_e	$0.510\ 998\ 910(13)$ MeV/c^2 $= 9.109\ 382\ 15(45)\times10^{-31}$ kg	25, 50
proton mass	m_p	$938.272\ 013(23)$ MeV/c^2 $= 1.672\ 621\ 637(83)\times10^{-27}$ kg	25, 50
		$= 1.007\ 276\ 466\ 77(10)$ u $= 1836.152\ 672\ 47(80)\ m_e$	0.10, 0.43
deuteron mass	m_d	$1875.612\ 793(47)$ MeV/c^2	25
unified atomic mass unit (u)	(mass ^{12}C atom)/12 = (1 g)/(N_A mol)	$931.494\ 028(23)$ MeV/c^2 $= 1.660\ 538\ 782(83)\times10^{-27}$ kg	25, 50
permittivity of free space	$\epsilon_0 = 1/\mu_0 c^2$	$8.854\ 187\ 817\ldots\times10^{-12}$ F m^{-1}	exact
permeability of free space	μ_0	$4\pi\times10^{-7}$ N A^{-2} $= 12.566\ 370\ 614\ldots\times10^{-7}$ N A^{-2}	exact
fine-structure constant	$\alpha = e^2/4\pi\epsilon_0\hbar c$	$7.297\ 352\ 5376(50)\times10^{-3} = 1/137.035\ 999\ 679(94)^\dagger$	0.68, 0.68
classical electron radius	$r_e = e^2/4\pi\epsilon_0 m_e c^2$	$2.817\ 940\ 2894(58)\times10^{-15}$ m	2.1
(e^- Compton wavelength)/2π	$\lambda\!\!\!^{-}_e = \hbar/m_e c = r_e\alpha^{-1}$	$3.861\ 592\ 6459(53)\times10^{-13}$ m	1.4
Bohr radius ($m_{\text{nucleus}} = \infty$)	$a_\infty = 4\pi\epsilon_0\hbar^2/m_e e^2 = r_e\alpha^{-2}$	$0.529\ 177\ 208\ 59(36)\times10^{-10}$ m	0.68
wavelength of 1 eV/c particle	$hc/(1\text{ eV})$	$1.239\ 841\ 875(31)\times10^{-6}$ m	25
Rydberg energy	$hcR_\infty = m_e e^4/2(4\pi\epsilon_0)^2\hbar^2 = m_e c^2\alpha^2/2$	$13.605\ 691\ 93(34)$ eV	25
Thomson cross section	$\sigma_T = 8\pi r_e^2/3$	$0.665\ 245\ 8558(27)$ barn	4.1
Bohr magneton	$\mu_B = e\hbar/2m_e$	$5.788\ 381\ 7555(79)\times10^{-11}$ MeV T^{-1}	1.4
nuclear magneton	$\mu_N = e\hbar/2m_p$	$3.152\ 451\ 2326(45)\times10^{-14}$ MeV T^{-1}	1.4
electron cyclotron freq./field	$\omega^e_{\text{cycl}}/B = e/m_e$	$1.758\ 820\ 150(44)\times10^{11}$ rad s^{-1} T^{-1}	25
proton cyclotron freq./field	$\omega^p_{\text{cycl}}/B = e/m_p$	$9.578\ 833\ 92(24)\times10^{7}$ rad s^{-1} T^{-1}	25
gravitational constant‡	G_N	$6.674\ 28(67)\times10^{-11}$ m^3 kg^{-1} s^{-2}	1.0×10^5
		$= 6.708\ 81(67)\times10^{-39}\ \hbar c\ (\text{GeV}/c^2)^{-2}$	1.0×10^5
standard gravitational accel.	g_N	$9.806\ 65$ m s^{-2}	exact
Avogadro constant	N_A	$6.022\ 141\ 79(30)\times10^{23}$ mol^{-1}	50
Boltzmann constant	k	$1.380\ 6504(24)\times10^{-23}$ J K^{-1}	1700
		$= 8.617\ 343(15)\times10^{-5}$ eV K^{-1}	1700
molar volume, ideal gas at STP	$N_A k(273.15\text{ K})/(101\ 325\text{ Pa})$	$22.413\ 996(39)\times10^{-3}$ m^3 mol^{-1}	1700
Wien displacement law constant	$b = \lambda_{\max}T$	$2.897\ 7685(51)\times10^{-3}$ m K	1700
Stefan-Boltzmann constant	$\sigma = \pi^2k^4/60\hbar^3c^2$	$5.670\ 400(40)\times10^{-8}$ W m^{-2} K^{-4}	7000
Fermi coupling constant**	$G_F/(\hbar c)^3$	$1.166\ 37(1)\times10^{-5}$ GeV^{-2}	9000
weak-mixing angle	$\sin^2\hat\theta(M_Z)$ ($\overline{\text{MS}}$)	$0.231\ 19(14)^{\dagger\dagger}$	6.5×10^5
$W^\pm$ boson mass	m_W	$80.398(25)$ GeV/c^2	3.6×10^5
Z^0 boson mass	m_Z	$91.1876(21)$ GeV/c^2	2.3×10^4
strong coupling constant	$\alpha_s(m_Z)$	$0.1176(20)$	1.7×10^7

$\pi = 3.141\ 592\ 653\ 589\ 793\ 238$ $\quad$ $e = 2.718\ 281\ 828\ 459\ 045\ 235$ $\quad$ $\gamma = 0.577\ 215\ 664\ 901\ 532\ 861$

1 in $\equiv$ 0.0254 m $\quad$ 1 G $\equiv 10^{-4}$ T $\quad$ 1 eV $= 1.602\ 176\ 487(40)\times10^{-19}$ J $\quad$ kT at 300 K $= [38.681\ 685(68)]^{-1}$ eV

1 Å $\equiv$ 0.1 nm $\quad$ 1 dyne $\equiv 10^{-5}$ N $\quad$ 1 eV/c^2 $= 1.782\ 661\ 758(44)\times10^{-36}$ kg $\quad$ 0 °C $\equiv$ 273.15 K

1 barn $\equiv 10^{-28}$ m^2 $\quad$ 1 erg $\equiv 10^{-7}$ J $\quad$ $2.997\ 924\ 58\times10^9$ esu = 1 C $\quad$ 1 atmosphere $\equiv$ 760 Torr $\equiv$ 101 325 Pa

* The meter is the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second.

† At $Q^2 = 0$. At $Q^2 \approx m_W^2$ the value is $\sim 1/128$.

‡ Absolute lab measurements of G_N have been made only on scales of about 1 cm to 1 m.

** See the discussion in Sec. 10, "Electroweak model and constraints on new physics."

†† The corresponding $\sin^2\theta$ for the effective angle is 0.23149(13).

2. ASTROPHYSICAL CONSTANTS AND PARAMETERS

Table 2.1. Revised May 2008 by E. Bergren and D.E. Groom (LBNL). The figures in parentheses after some values give the one standard deviation uncertainties in the last digit(s). Physical constants are from Ref. 1. While every effort has been made to obtain the most accurate current values of the listed quantities, the table does not represent a critical review or adjustment of the constants, and is not intended as a primary reference. The values and uncertainties for the cosmological parameters depend on the exact data sets, priors, and basis parameters used in the fit. Many of the parameters reported in this table are derived parameters or have non-Gaussian likelihoods. The quoted errors may be highly correlated with those of other parameters, so care must be taken in propagating them. Unless otherwise specified, cosmological parameters are best fits of a spatially-flat ΛCDM cosmology with a power-law initial spectrum to WMAP 3-year data alone [2]. For more information see Ref. 3 and the original papers.

Quantity	Symbol, equation	Value	Reference, footnote
speed of light	c	$299\,792\,458$ m s^{-1}	exact[4]
Newtonian gravitational constant	G_N	$6.674\,3(7) \times 10^{-11}$ m^3 kg^{-1} s^{-2}	[1]
Planck mass	$\sqrt{\hbar c/G_N}$	$1.220\,89(6) \times 10^{19}$ GeV/c^2 $= 2.176\,44(11) \times 10^{-8}$ kg	[1]
Planck length	$\sqrt{\hbar G_N/c^3}$	$1.616\,24(8) \times 10^{-35}$ m	[1]
standard gravitational acceleration	g_N	$9.806\,65$ m s^{-2}	exact[1]
jansky (flux density)	Jy	10^{-26} W m^{-2} Hz^{-1}	definition
tropical year (equinox to equinox) (2007)	yr	$31\,556\,925.2$ s $\approx \pi \times 10^7$ s	[5]
sidereal year (fixed star to fixed star) (2007)		$31\,558\,149.8$ s $\approx \pi \times 10^7$ s	[5]
mean sidereal day (2007) (time between vernal equinox transits)		$23^{\rm h}\,56^{\rm m}\,04^{\rm s}\!.090\,53$	[5]
astronomical unit	AU, A	$149\,597\,870\,700(3)$ m	[6]
parsec (1 AU/1 arc sec)	pc	$3.085\,677\,6 \times 10^{16}$ m $= 3.262\ldots$ ly	[7]
light year (deprecated unit)	ly	$0.306\,6\ldots$ pc $= 0.946\,053\ldots \times 10^{16}$ m	
Schwarzschild radius of the Sun	$2G_N M_\odot/c^2$	$2.953\,250\,077\,0(2)$ km	[8]
Solar mass	$M_\odot$	$1.988\,4(2) \times 10^{30}$ kg	[9]
Solar equatorial radius	$R_\odot$	$6.9551(3) \times 10^8$ m	[10]
Solar luminosity	$L_\odot$	$3.842\,7(14) \times 10^{26}$ W	[11]
Schwarzschild radius of the Earth	$2G_N M_\oplus/c^2$	$8.870\,055\,881$ mm	[12]
Earth mass	$M_\oplus$	$5.972\,2(6) \times 10^{24}$ kg	[13]
Earth mean equatorial radius	$R_\oplus$	$6.378\,137 \times 10^6$ m	[5]
luminosity conversion (deprecated)	L	$3.02 \times 10^{28} \times 10^{-0.4\,M_{\rm bol}}$ W ($M_{\rm bol}$ = absolute bolometric magnitude = bolometric magnitude at 10 pc)	[14]
flux conversion (deprecated)	$\mathscr{F}$	$2.52 \times 10^{-8} \times 10^{-0.4\,m_{\rm bol}}$ W m^{-2} ($m_{\rm bol}$ = apparent bolometric magnitude)	from above
ABsolute monochromatic magnitude	AB	$-2.5 \log_{10} f_\nu - 56.10$ (for f_ν in W m^{-2} Hz^{-1}) $= -2.5 \log_{10} f_\nu + 8.90$ (for f_ν in Jy)	[15]
Solar velocity around center of Galaxy	Θ_0	$220(20)$ km s^{-1}	[16]
Solar distance from Galactic center	R_0	$8.0(5)$ kpc	[17]
local disk density	$\rho_{\rm disk}$	3–12 $\times 10^{-24}$ g cm^{-3} $\approx$ 2–7 GeV/c^2 cm^{-3}	[18]
local halo density	$\rho_{\rm halo}$	2–13 $\times 10^{-25}$ g cm^{-3} $\approx$ 0.1–0.7 GeV/c^2cm^{-3}	[19]
present day CMB temperature	T_0	$2.725(1)$ K	[20]
present day CMB dipole amplitude		$3.358(17)$ mK	[21]
Solar velocity with respect to CMB		$369(2)$ km/s towards $(\ell, b) = (263.86(4)^\circ, 48.24(10)^\circ)$	[21]
Local Group velocity with respect to CMB	$v_{\rm LG}$	$627(22)$ km s^{-1} towards $(\ell, b) = (276(3)^\circ, 30(3)^\circ$	[22]
entropy density/Boltzmann constant	s/k	$2\,889.2\,(T/2.725)^3$ cm^{-3}	[14]
number density of CMB photons	n_γ	$410.5(T/2.725)^3$ cm^{-3}	[23]
present day Hubble expansion rate	H_0	$100\,h$ km s^{-1} Mpc^{-1} $= h \times (9.777\,752$ Gyr$)^{-1}$	[24]
present day normalized Hubble expansion rate‡	h	$0.73(3)$	[2,3]
Hubble length	c/H_0	$0.925\,063 \times 10^{26}\,h^{-1}$ m $\approx 1.27 \times 10^{26}$ m	
scale factor for cosmological constant	$c^2/3H_0^2$	$2.852 \times 10^{51}\,h^{-2}$ m^2	
critical density of the Universe	$\rho_{\rm c} = 3H_0^2/8\pi G_N$	$2.775\,366\,27 \times 10^{11}\,h^2\,M_\odot$Mpc^{-3} $= 1.878\,35(19) \times 10^{-29}\,h^2$ g cm^{-3} $= 1.053\,68(11) \times 10^{-5}\,h^2$ (GeV/c^2) cm^{-3}	
pressureless matter density of the Universe‡	$\Omega_{\rm m} = \rho_{\rm m}/\rho_{\rm c}$	$0.128(8)\,h^{-2} \approx 0.24$ (WMAP3)	[2,3]
		$0.132(4)\,h^{-2} \Rightarrow 0.27(2)$ (ALL mean)	[2]
baryon density of the Universe‡	$\Omega_{\rm b} = \rho_{\rm b}/\rho_{\rm c}$	$0.0223(7)\,h^{-2} \approx 0.0425$	[2,3]
dark matter density of the universe‡	$\Omega_{\rm dm} = \Omega_{\rm m} - \Omega_{\rm b}$	$0.105(8)\,h^{-2} \approx 0.20$	[2]
dark energy density of the Universe‡	Ω_Λ	$0.73(3)$	[25]
Hubble length	c/H_0	$0.925\,063 \times 10^{26}\,h^{-1}$ m $\approx 1.27 \times 10^{26}$ m	
radiation density of the Universe‡	$\Omega_\gamma = \rho_\gamma/\rho_{\rm c}$	$2.471 \times 10^{-5}(T/2.725)^4\,h^{-2} \approx 4.6 \times 10^{-5}$	[23]
neutrino density of the Universe‡	Ω_ν	$0.0005 < \Omega_\nu h^{-2} < 0.023 \Rightarrow 0.001 < \Omega_\nu < 0.05$	[26]
total energy density of the Universe‡	$\Omega_{\rm tot} = \Omega_{\rm m} + \ldots + \Omega_\Lambda$	$1.011(12)$	[2,27]