

Memorandum № 5

Astrodynamical Constants

Universal Constants

Sym.	Meaning	Value	Source
a_δ	semi-major axis of the WGS84 reference ellipsoid of the Earth	6 378 137.0 m	[9, p. 3-2]
c_0	speed of light <i>in vacuo</i>	299 792 458 m s ⁻¹	[6, p. 637]
f_δ	flattening of the WGS84 reference ellipsoid of the Earth	1/298.257 223 563	[9, p. 3-2]
f_ζ	polar Moon flattening	1/581.9	[1, p. 898]
g_0	standard acceleration due to gravity	9.806 65 $\frac{\text{m}}{\text{s}^2}$	[5, p. 364]
G	NEWTONIAN constant of gravitation	$6.674\,28(67) \cdot 10^{-11} \frac{\text{m}^3}{\text{kg} \cdot \text{s}^2}$	[6, pp. 686–689]
k	GAUSSIAN gravitational constant	$1.720\,209\,895 \cdot 10^{-2}$	[7, p. 58]
r_δ	Earth's volumetric mean radius	$6.371\,000\,79 \cdot 10^6$ m	[9, p. 3-7]
r_ζ	volumetric mean Moon radius (MMR)	$1.737\,15 \cdot 10^6 (\pm 10)$ m	[1, p. 898]
$r_{\zeta \text{ pol}}$	polar Moon radius	$1.735\,66 \cdot 10^6$ m	[1, p. 898]
$r_{\zeta \text{ eq}}$	mean equatorial Moon radius	$1.738\,64 \cdot 10^6$ m	[1, p. 898]
μ_δ	Earth's standard gravitational parameter	$3.986\,004\,418 \cdot 10^{14} (\pm 8 \cdot 10^5) \frac{\text{m}^3}{\text{s}^2}$ (TCB-compatible) $3.986\,004\,415 \cdot 10^{14} (\pm 8 \cdot 10^5) \frac{\text{m}^3}{\text{s}^2}$ (TT-compatible) $3.986\,004\,356 \cdot 10^{14} (\pm 8 \cdot 10^5) \frac{\text{m}^3}{\text{s}^2}$ (TDB-compatible)	[12] ¹
μ_ζ	Moon's standard gravitational parameter	$4.902\,801\,076 \cdot 10^{12} (\pm 8.1 \cdot 10^4) \frac{\text{m}^3}{\text{s}^2}$	[14, p. 305]
μ_\odot	Sun's standard gravitational parameter	$1.327\,124\,420\,99 \cdot 10^{20} (\pm 1.0 \cdot 10^{10}) \frac{\text{m}^3}{\text{s}^2}$ (TCB-comp.) $1.327\,124\,400\,41 \cdot 10^{20} (\pm 1.0 \cdot 10^{10}) \frac{\text{m}^3}{\text{s}^2}$ (TDB-comp.)	[2]
τ_A	light time for 1 AU	499.004 783 806 ($\pm 0.000\,000\,01$) s	[8]
ω_δ	Earth's nominal mean angular velocity	$7.292\,115 \cdot 10^{-5}$ rad s ⁻¹	[10, p. 19]

Conversion Factors

Conversion		Source
Astronomical Units → Meters	1 AU = 1.495 978 707 00 · 10 ¹¹ m (exact)	[3][11, p. 370 f.]
Julian Days → Seconds	1 d = 86 400 s	[13, p. 696]
Degrees → Radians	1° = 1° · $\frac{\pi}{180^\circ}$ rad ≈ 0,017453293 rad	

SI Prefixes

Prefix	Symbol	1000 ^m	10 ⁿ	Decimal	US English Word
yotta	Y	1000 ⁸	10 ²⁴	1 000 000 000 000 000 000 000 000	septillion
zetta	Z	1000 ⁷	10 ²¹	1 000 000 000 000 000 000 000	sextillion
exa	E	1000 ⁶	10 ¹⁸	1 000 000 000 000 000 000	quintillion
peta	P	1000 ⁵	10 ¹⁵	1 000 000 000 000 000	quadrillion

¹ As adopted by the IAU within the IAU 2009 System of Astronomical Constants [4, pp. 296 and 300].



tera	T	1000 ⁴	10 ¹²	1 000 000 000 000	trillion
giga	G	1000 ³	10 ⁹	1 000 000 000	billion
mega	M	1000 ²	10 ⁶	1 000 000	million
kilo	k	1000 ¹	10 ³	1 000	thousand
hecto	h	1000 ^{2/3}	10 ²	100	hundred
deca	da	1000 ^{1/3}	10 ¹	10	ten
		1000 ⁰	10 ⁰	1	one
deci	d	1000 ^{-1/3}	10 ⁻¹		0.1 tenth
centi	c	1000 ^{-2/3}	10 ⁻²		0.01 hundredth
milli	m	1000 ⁻¹	10 ⁻³		0.001 thousandth
micro	μ	1000 ⁻²	10 ⁻⁶		0.000 001 millionth
nano	n	1000 ⁻³	10 ⁻⁹		0.000 000 001 billionth
pico	p	1000 ⁻⁴	10 ⁻¹²		0.000 000 000 001 trillionth
femto	f	1000 ⁻⁵	10 ⁻¹⁵		0.000 000 000 000 001 quadrillionth
atto	a	1000 ⁻⁶	10 ⁻¹⁸		0.000 000 000 000 000 001 quintillionth
zepto	z	1000 ⁻⁷	10 ⁻²¹		0.000 000 000 000 000 000 001 sextillionth
yocto	y	1000 ⁻⁸	10 ⁻²⁴		0.000 000 000 000 000 000 000 001 septillionth

References

- ARAKI, H.; TAZAWA, S.; NODA, H.; ISHIHARA, Y.; GOOSSENS, S.; SASAKI, S.; KAWANO, N.; KAMIYA, I.; OTAKE, H.; OBERST, J.; SHUM, C.: *Lunar Global Shape and Polar Topography Derived from Kaguya-LALT Laser Altimetry*. In: *Science* **323** (5916): 897–900. 2009. DOI: [10.1126/science.1164146](https://doi.org/10.1126/science.1164146). [→ cited on page 1]
- IAU DIVISION I WORKING GROUP ON NUMERICAL STANDARDS FOR FUNDAMENTAL ASTRONOMY: *Astronomical Constants: Current Best Estimates (CBEs)*. Online available at http://maia.usno.navy.mil/NSFA/NSFA_cbe.html (retrieved 2017/10/05). [→ cited on page 1]
- INTERNATIONAL ASTRONOMICAL UNION (IAU) (ed.): *Resolution B2 of the XXVIII IAU General Assembly on the Re-Definition of the Astronomical Unit of Length*. 2012. Online available at https://www.iau.org/static/resolutions/IAU2012_English.pdf (retrieved 2017/10/05). [→ cited on page 1]
- LUZUM, Brian; CAPITAIN, Nicole; FIENGA, Agnès; FOLKNER, William; FUKUSHIMA, Toshio; HILTON, James; HOHENKERK, Catherine; KRASINSKY, George; PETIT, Gérard; PITJEVA, Elena; SOFFEL, Michael; WALLACE, Patrick: *The IAU 2009 system of astronomical constants: the report of the IAU working group on numerical standards for Fundamental Astronomy*. In: *Celestial Mechanics and Dynamical Astronomy* **110** (4): 293–304. Springer Netherlands, 2011. ISSN: 0923-2958. DOI: [10.1007/s10569-011-9352-4](https://doi.org/10.1007/s10569-011-9352-4). [→ cited on page 1]
- MOHR, Peter J.; TAYLOR, Barry N.: *CODATA recommended values of the fundamental physical constants: 1998*. In: *Review of Modern Physics* **72** (2): 351–495. American Physical Society, April 2000. DOI: [10.1103/RevModPhys.72.351](https://doi.org/10.1103/RevModPhys.72.351). [→ cited on page 1]
- MOHR, Peter J.; TAYLOR, Barry N.; NEWELL, David B.: *CODATA recommended values of the fundamental physical constants: 2006*. In: *Review of Modern Physics* **80** (2): 633–730. American Physical Society, 2008. ISSN: 1539-0756. DOI: [10.1103/RevModPhys.80.633](https://doi.org/10.1103/RevModPhys.80.633). [→ cited on page 1]
- MÜLLER, Edith A. (ed.): *Proceedings of the Sixteenth General Assembly, Grenoble 1976*. Transactions of the International Astronomical Union (XVIB). International Astronomical Union, Kluwer Academic Publishers, 1977. ISBN: 90-277-0836-3. [→ cited on page 1]
- NASA/JPL (ed.): *Astrodynamic Constants*. NASA/JPL/SSD website. 2011. Online available at <http://ssd.jpl.nasa.gov/?constants> (retrieved 2011/04/26). [→ cited on page 1]
- NATIONAL IMAGERY AND MAPPING AGENCY (NIMA) (ed.): *World Geodetic System 1984: Its Definition and Relationships with Local Geodetic Systems*. Third edition. U.S. Department of Defense, June 23, 2004. Technical Report NIMA TR8350.2, NIMA stock no. DMATR83502WGS84, NSN 7643-01-402-0347. Online available at <http://earth-info.nga.mil/GandG/publications/tr8350.2/wgs84fin.pdf> (retrieved 2017/10/05). [→ cited on page 1]
- PETIT, Gérard; LUZUM, Brian (eds.): *IERS Conventions (2010)*. International Earth Rotation and Reference Systems Service (IERS), published by: Verlag des Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main, 2010. IERS Technical Note No. 36. Online available at <http://www.iers.org/TN36/>. [→ cited on page 1]
- PITJEVA, E.; STANDISH, E.: *Proposals for the masses of the three largest asteroids, the Moon-Earth mass ratio and the Astronomical Unit*. In: *Celestial Mechanics and Dynamical Astronomy* **103** (4): 365–372. Springer Netherlands, 2009. ISSN: 0923-2958. DOI: [10.1007/s10569-009-9203-8](https://doi.org/10.1007/s10569-009-9203-8). [→ cited on page 1]
- RIES, J. C.; EANES, R. J.; SHUM, C. K.; WATKINS, M. M.: *Progress in the determination of the gravitational coefficient of the Earth*. In: *Geophysical Research Letters* **19** (6): 529–531. 1992. DOI: [10.1029/92GL00259](https://doi.org/10.1029/92GL00259). [→ cited on page 1]
- SEIDELMANN, P. Kenneth (ed.): *Explanatory Supplement to the Astronomical Almanac*. First paperback impression. University Science Books, Sausalito, California, USA, 2006. ISBN: 978-1-891389-45-0. [→ cited on page 1]
- WIECZOREK, Mark A.; JOLLIFF, Bradley L.; KHAN, Amir; PRITCHARD, Matthew E.; WEISS, Benjamin P.; WILLIAMS, James G.; HOOD, Lon L.; RICHTER, Kevin; NEAL, Clive R.; SHEARER, Charles K.; MCCALLUM, I. Stewart; TOMPKINS, Stephanie; HAWKE, B. Ray; PETERSON, Chris; GILLIS, Jeffrey J.; BUSSEY, Ben: *The Constitution and Structure of the Lunar Interior*. In: *Reviews in Mineralogy and Geochemistry* **60** (1): 221–364. 2006. DOI: [10.2138/rmg.2006.60.3](https://doi.org/10.2138/rmg.2006.60.3). [→ cited on page 1]