

APPENDIX F

Numerical Constants

FUNDAMENTAL PHYSICAL CONSTANTS*

Name	Symbol	Value
Speed of light	c	2.99792458×10^8 m/s
Magnitude of charge of electron	e	$1.602176462(63) \times 10^{-19}$ C
Gravitational constant	G	$6.673(10) \times 10^{-11}$ N · m ² /kg ²
Planck's constant	h	$6.62606876(52) \times 10^{-34}$ J · s
Boltzmann constant	k	$1.3806503(24) \times 10^{-23}$ J/K
Avogadro's number	N_A	$6.02214199(47) \times 10^{23}$ molecules/mol
Gas constant	R	8.314472(15) J/mol · K
Mass of electron	m_e	$9.10938188(72) \times 10^{-31}$ kg
Mass of proton	m_p	$1.67262158(13) \times 10^{-27}$ kg
Mass of neutron	m_n	$1.67492716(13) \times 10^{-27}$ kg
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ Wb/A · m
Permittivity of free space	$\epsilon_0 = 1/\mu_0 c^2$	$8.854187817 \dots \times 10^{-12}$ C ² /N · m ²
	$1/4\pi\epsilon_0$	$8.987551787 \dots \times 10^9$ N · m ² /C ²

OTHER USEFUL CONSTANTS*

Mechanical equivalent of heat		4.186 J/cal (15° calorie)
Standard atmospheric pressure	1 atm	1.01325×10^5 Pa
Absolute zero	0 K	-273.15°C
Electron volt	1 eV	$1.602176462(63) \times 10^{-19}$ J
Atomic mass unit	1 u	$1.66053873(13) \times 10^{-27}$ kg
Electron rest energy	$m_e c^2$	0.510998902(21) MeV
Volume of ideal gas (0°C and 1 atm)		22.413996(39) liter/mol
Acceleration due to gravity (standard)	g	9.80665 m/s ²

*Source: National Institute of Standards and Technology (<http://physics.nist.gov/cuu>). Numbers in parentheses show the uncertainty in the final digits of the main number; for example, the number 1.6454(21) means 1.6454 ± 0.0021 . Values shown without uncertainties are exact.

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ASTRONOMICAL DATA†

Body	Mass (kg)	Radius (m)	Orbit radius (m)	Orbit period
Sun	1.99×10^{30}	6.96×10^8	—	—
Moon	7.35×10^{22}	1.74×10^6	3.84×10^8	27.3 d
Mercury	3.30×10^{23}	2.44×10^6	5.79×10^{10}	88.0 d
Venus	4.87×10^{24}	6.05×10^6	1.08×10^{11}	224.7 d
Earth	5.97×10^{24}	6.38×10^6	1.50×10^{11}	365.3 d
Mars	6.42×10^{23}	3.40×10^6	2.28×10^{11}	687.0 d
Jupiter	1.90×10^{27}	6.91×10^7	7.78×10^{11}	11.86 y
Saturn	5.68×10^{26}	6.03×10^7	1.43×10^{12}	29.45 y
Uranus	8.68×10^{25}	2.56×10^7	2.87×10^{12}	84.02 y
Neptune	1.02×10^{26}	2.48×10^7	4.50×10^{12}	164.8 y
Pluto	1.31×10^{22}	1.15×10^6	5.91×10^{12}	247.9 y

†Source: NASA Jet Propulsion Laboratory Solar System Dynamics Group (<http://ssd.jpl.nasa.gov>), and P. Kenneth Seidelmann, ed., *Explanatory Supplement to the Astronomical Almanac* (University Science Books, Mill Valley, CA, 1992), pp. 704–706. For each body, “radius” is its radius at its equator and “orbit radius” is its average distance from the sun (for the planets) or from the earth (for the moon).

PREFIXES FOR POWERS OF 10

Power of ten	Prefix	Abbreviation	Pronunciation
10^{-24}	yocto-	y	yoc-toe
10^{-21}	zepto-	z	zep-toe
10^{-18}	atto-	a	at-toe
10^{-15}	femto-	f	fem-toe
10^{-12}	pico-	p	pee-koe
10^{-9}	nano-	n	nan-oe
10^{-6}	micro-	μ	my-crow
10^{-3}	milli-	m	mil-i
10^{-2}	centi-	c	cen-ti
10^3	kilo-	k	kil-oe
10^6	mega-	M	meg-a
10^9	giga-	G	jig-a or gig-a
10^{12}	tera-	T	ter-a
10^{15}	peta-	P	pet-a
10^{18}	exa-	E	ex-a
10^{21}	zetta-	Z	zet-a
10^{24}	yotta-	Y	yot-a

Examples:

1 femtometer = 1 fm = 10^{-15} m
 1 picosecond = 1 ps = 10^{-12} s
 1 nanocoulomb = 1 nC = 10^{-9} C
 1 microkelvin = 1 μ K = 10^{-6} K

1 millivolt = 1 mV = 10^{-3} V
 1 kilopascal = 1 kPa = 10^3 Pa
 1 megawatt = 1 MW = 10^6 W
 1 gigahertz = 1 GHz = 10^9 Hz

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APPENDIX E

Unit Conversion Factors

LENGTH

1 m = 100 cm = 1000 mm = $10^6 \mu\text{m} = 10^9 \text{nm}$
1 km = 1000 m = 0.6214 mi
1 m = 3.281 ft = 39.37 in.
1 cm = 0.3937 in.
1 in. = 2.540 cm
1 ft = 30.48 cm
1 yd = 91.44 cm
1 mi = 5280 ft = 1.609 km
1 Å = $10^{-10} \text{m} = 10^{-8} \text{cm} = 10^{-1} \text{nm}$
1 nautical mile = 6080 ft
1 light year = $9.461 \times 10^{15} \text{m}$

AREA

1 cm² = 0.155 in.²
1 m² = $10^4 \text{cm}^2 = 10.76 \text{ft}^2$
1 in.² = 6.452 cm²
1 ft² = 144 in.² = 0.0929 m²

VOLUME

1 liter = 1000 cm³ = $10^{-3} \text{m}^3 = 0.03531 \text{ft}^3 = 61.02 \text{in.}^3$
1 ft³ = 0.02832 m³ = 28.32 liters = 7.477 gallons
1 gallon = 3.788 liters

TIME

1 min = 60 s
1 h = 3600 s
1 d = 86,400 s
1 y = 365.24 d = $3.156 \times 10^7 \text{s}$

ANGLE

1 rad = $57.30^\circ = 180^\circ/\pi$
1° = 0.01745 rad = $\pi/180 \text{rad}$
1 revolution = $360^\circ = 2\pi \text{rad}$
1 rev/min (rpm) = 0.1047 rad/s

SPEED

1 m/s = 3.281 ft/s
1 ft/s = 0.3048 m/s
1 mi/min = 60 mi/h = 88 ft/s
1 km/h = 0.2778 m/s = 0.6214 mi/h
1 mi/h = 1.466 ft/s = 0.4470 m/s = 1.609 km/h
1 furlong/fortnight = $1.662 \times 10^{-4} \text{m/s}$

ACCELERATION

1 m/s² = 100 cm/s² = 3.281 ft/s²
1 cm/s² = 0.01 m/s² = 0.03281 ft/s²
1 ft/s² = 0.3048 m/s² = 30.48 cm/s²
1 mi/h · s = 1.467 ft/s²

MASS

1 kg = 10³ g = 0.0685 slug
1 g = $6.85 \times 10^{-5} \text{slug}$
1 slug = 14.59 kg
1 u = $1.661 \times 10^{-27} \text{kg}$
1 kg has a weight of 2.205 lb when $g = 9.80 \text{m/s}^2$

FORCE

1 N = 10⁵ dyn = 0.2248 lb
1 lb = 4.448 N = $4.448 \times 10^5 \text{dyn}$

PRESSURE

1 Pa = 1 N/m² = $1.450 \times 10^{-4} \text{lb/in.}^2 = 0.209 \text{lb/ft}^2$
1 bar = 10⁵ Pa
1 lb/in.² = 6895 Pa
1 lb/ft² = 47.88 Pa
1 atm = $1.013 \times 10^5 \text{Pa} = 1.013 \text{bar}$
= $14.7 \text{lb/in.}^2 = 2117 \text{lb/ft}^2$
1 mm Hg = 1 torr = 133.3 Pa.

ENERGY

1 J = 10⁷ ergs = 0.239 cal
1 cal = 4.186 J (based on 15° calorie)
1 ft · lb = 1.356 J
1 Btu = 1055 J = 252 cal = 778 ft · lb
1 eV = $1.602 \times 10^{-19} \text{J}$
1 kWh = $3.600 \times 10^6 \text{J}$

MASS-ENERGY EQUIVALENCE

1 kg ↔ $8.988 \times 10^{16} \text{J}$
1 u ↔ 931.5 MeV
1 eV ↔ $1.074 \times 10^{-9} \text{u}$

POWER

1 W = 1 J/s
1 hp = 746 W = 550 ft · lb/s
1 Btu/h = 0.293 W