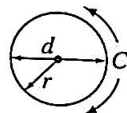
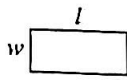
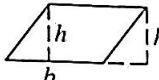
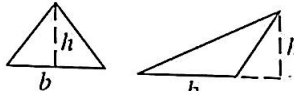
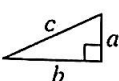
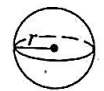
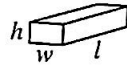
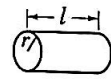



Useful Geometry Formulas—Areas, Volumes

Circumference of circle	$C = \pi d = 2\pi r$	
Area of circle	$A = \pi r^2 = \frac{\pi d^2}{4}$	
Area of rectangle	$A = lw$	
Area of parallelogram	$A = bh$	
Area of triangle	$A = \frac{1}{2}hb$	
Right triangle (Pythagoras)	$c^2 = a^2 + b^2$	
Sphere: surface area volume	$A = 4\pi r^2$ $V = \frac{4}{3}\pi r^3$	
Rectangular solid: volume	$V = lwh$	
Cylinder (right): surface area volume	$A = 2\pi rl + 2\pi r^2$ $V = \pi r^2 l$	
Right circular cone: surface area volume	$A = \pi r^2 + \pi r \sqrt{r^2 + h^2}$ $V = \frac{1}{3}\pi r^2 h$	

Exponents [See Appendix A-2 for details]

$$(a^n)(a^m) = a^{n+m} \quad [\text{Example: } (a^3)(a^2) = a^5]$$

$$(a^n)(b^n) = (ab)^n \quad [\text{Example: } (a^3)(b^3) = (ab)^3]$$

$$(a^n)^m = a^{nm} \quad [\text{Example: } (a^3)^2 = a^6]$$

$$[\text{Example: } (a^{\frac{1}{4}})^4 = a]$$

$$a^{-1} = \frac{1}{a} \quad a^{-n} = \frac{1}{a^n} \quad a^0 = 1$$

$$a^{\frac{1}{2}} = \sqrt{a} \quad a^{\frac{1}{4}} = \sqrt[4]{a}$$

$$(a^n)(a^{-m}) = \frac{a^n}{a^m} = a^{n-m} \quad [\text{Ex.: } (a^5)(a^{-2}) = a^3]$$

$$\frac{a^n}{b^n} = \left(\frac{a}{b}\right)^n$$

Quadratic Formula [Appendix A-4]

Equation with unknown x , in the form

$$ax^2 + bx + c = 0,$$

has solutions

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Logarithms [Appendix A-8; Table p. A-11]

If $y = 10^x$, then $x = \log_{10} y = \log y$.

If $y = e^x$, then $x = \log_e y = \ln y$.

$$\log(ab) = \log a + \log b$$

$$\log\left(\frac{a}{b}\right) = \log a - \log b$$

$$\log a^n = n \log a$$

Binomial Expansion [Appendix A-5]

$$(1+x)^n = 1 + nx + \frac{n(n-1)}{2 \cdot 1}x^2 + \frac{n(n-1)(n-2)}{3 \cdot 2 \cdot 1}x^3 + \dots \quad [\text{for } x^2 < 1]$$

$$\approx 1 + nx \quad \text{if } x \ll 1$$

$$[\text{Example: } (1 + 0.01)^3 \approx 1.03]$$

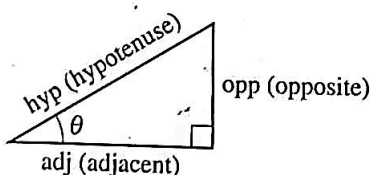
$$[\text{Example: } \frac{1}{\sqrt{0.99}} = \frac{1}{\sqrt{1-0.01}} = (1-0.01)^{-\frac{1}{2}} \approx 1 - (-\frac{1}{2})(0.01) \approx 1.005]$$

Fractions

$\frac{a}{b} = \frac{c}{d}$ is the same as $ad = bc$

$$\left(\frac{\frac{a}{b}}{\frac{c}{d}}\right) = \frac{ad}{bc}$$

Trigonometric Formulas [Appendix A-7]



$$\sin \theta = \frac{\text{opp}}{\text{hyp}}$$

$$\cos \theta = \frac{\text{adj}}{\text{hyp}}$$

$$\tan \theta = \frac{\text{opp}}{\text{adj}}$$

$$\text{adj}^2 + \text{opp}^2 = \text{hyp}^2 \quad (\text{Pythagorean theorem})$$

$$\tan \theta = \frac{\sin \theta}{\cos \theta}$$

$$\sin^2 \theta + \cos^2 \theta = 1$$

$$\sin 2\theta = 2 \sin \theta \cos \theta$$

$$\cos 2\theta = (\cos^2 \theta - \sin^2 \theta) = (1 - 2 \sin^2 \theta) = (2 \cos^2 \theta - 1)$$

$$\sin(180^\circ - \theta) = \sin \theta$$

$$\cos(180^\circ - \theta) = -\cos \theta$$

$$\sin(90^\circ - \theta) = \cos \theta$$

$$\cos(90^\circ - \theta) = \sin \theta \quad \left. \vphantom{\begin{matrix} \sin(90^\circ - \theta) = \cos \theta \\ \cos(90^\circ - \theta) = \sin \theta \end{matrix}} \right\} [0 < \theta < 90^\circ]$$

$$\sin \frac{1}{2} \theta = \sqrt{(1 - \cos \theta)/2}$$

$$\cos \frac{1}{2} \theta = \sqrt{(1 + \cos \theta)/2}$$

$$\sin \theta \approx \theta \quad [\text{for small } \theta \approx 0.2 \text{ rad}]$$

$$\cos \theta \approx 1 - \frac{\theta^2}{2} \quad [\text{for small } \theta \approx 0.2 \text{ rad}]$$

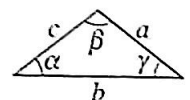
$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$

$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$

For any triangle:

$$c^2 = a^2 + b^2 - 2ab \cos \gamma \quad (\text{law of cosines})$$

$$\frac{\sin \alpha}{a} = \frac{\sin \beta}{b} = \frac{\sin \gamma}{c} \quad (\text{law of sines})$$



Unit Conversions (Equivalents)

Length

1 in. = 2.54 cm
 1 cm = 0.3937 in.
 1 ft = 30.48 cm
 1 m = 39.37 in. = 3.281 ft
 1 mi = 5280 ft = 1.609 km
 1 km = 0.6214 mi
 1 nautical mile (U.S.) = 1.151 mi = 6076 ft = 1.852 km
 1 fermi = 1 femtometer (fm) = 10^{-15} m
 1 angstrom (Å) = 10^{-10} m = 0.1 nm
 1 light-year (ly) = 9.461×10^{15} m
 1 parsec = 3.26 ly = 3.09×10^{16} m

Volume

1 liter (L) = 1000 mL = 1000 cm^3 = $1.0 \times 10^{-3} \text{ m}^3$ =
 1.057 qt (U.S.) = 61.02 in.³
 1 gal (U.S.) = 4 qt (U.S.) = 231 in.³ = 3.785 L =
 0.8327 gal (British)
 1 quart (U.S.) = 2 pints (U.S.) = 946 mL
 1 pint (British) = 1.20 pints (U.S.) = 568 mL
 1 m³ = 35.31 ft³

Speed

1 mi/h = 1.467 ft/s = 1.609 km/h = 0.447 m/s
 1 km/h = 0.278 m/s = 0.621 mi/h
 1 ft/s = 0.305 m/s = 0.682 mi/h
 1 m/s = 3.281 ft/s = 3.600 km/h = 2.237 mi/h
 1 knot = 1.151 mi/h = 0.5144 m/s

Angle

1 radian (rad) = 57.30° = $57^\circ 18'$
 1° = 0.01745 rad
 1 rev/min (rpm) = 0.1047 rad/s

Time

1 day = 8.64×10^4 s
 1 year = 3.156×10^7 s

Mass

1 atomic mass unit (u) = 1.6605×10^{-27} kg
 1 kg = 0.0685 slug
 [1 kg has a weight of 2.20 lb where $g = 9.80 \text{ m/s}^2$]

Force

1 lb = 4.45 N
 1 N = 10^5 dyne = 0.225 lb

Energy and Work

1 J = 10^7 ergs = 0.738 ft·lb
 1 ft·lb = 1.36 J = 1.29×10^{-3} Btu = 3.24×10^{-6} kcal
 1 kcal = 4.186×10^3 J = 3.97 Btu
 1 eV = 1.602×10^{-19} J
 1 kWh = 3.60×10^6 J = 860 kcal

Power

1 W = 1 J/s = 0.738 ft·lb/s = 3.42 Btu/h
 1 hp = 550 ft·lb/s = 746 W

Pressure

1 atm = 1.013 bar = 1.013×10^5 N/m²
 = 14.7 lb/in.² = 760 torr
 1 lb/in.² = 6.90×10^3 N/m²
 1 Pa = 1 N/m² = 1.45×10^{-4} lb/in.²

SI Derived Units and Their Abbreviations

Quantity	Unit	Abbreviation	In Terms of Base Units [†]
Force	newton	N	kg · m/s ²
Energy and work	joule	J	kg · m ² /s ²
Power	watt	W	kg · m ² /s ³
Pressure	pascal	Pa	kg/(m · s ²)
Frequency	hertz	Hz	s ⁻¹
Electric charge	coulomb	C	A · s
Electric potential	volt	V	kg · m ² /(A · s ³)
Electric resistance	ohm	Ω	kg · m ² /(A ² · s ³)
Capacitance	farad	F	A ² · s ⁴ /(kg · m ²)
Magnetic field	tesla	T	kg/(A · s ²)
Magnetic flux	weber	Wb	kg · m ² /(A · s ²)
Inductance	henry	H	kg · m ² /(s ² · A ²)

[†] kg = kilogram (mass), m = meter (length), s = second (time), A = ampere (electric current).

Metric (SI) Multipliers

Prefix	Abbreviation	Value
yotta	Y	10^{24}
zeta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^9
mega	M	10^6
kilo	k	10^3
hecto	h	10^2
deka	da	10^1
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

Fundamental Constants

Quantity	Symbol	Approximate Value	Current Best Value [†]
Speed of light in vacuum	c	3.00×10^8 m/s	2.99792458×10^8 m/s
Gravitational constant	G	6.67×10^{-11} N·m ² /kg ²	$6.6742(10) \times 10^{-11}$ N·m ² /kg ²
Avogadro's number	N_A	6.02×10^{23} mol ⁻¹	$6.0221415(10) \times 10^{23}$ mol ⁻¹
Gas constant	R	8.314 J/mol·K = 1.99 cal/mol·K = 0.0821 L·atm/mol·K	$8.314472(15)$ J/mol·K
Boltzmann's constant	k	1.38×10^{-23} J/K	$1.3806505(24) \times 10^{-23}$ J/K
Charge on electron	e	1.60×10^{-19} C	$1.60217653(14) \times 10^{-19}$ C
Stefan-Boltzmann constant	σ	5.67×10^{-8} W/m ² ·K ⁴	$5.670400(40) \times 10^{-8}$ W/m ² ·K ⁴
Permittivity of free space	$\epsilon_0 = (1/c^2\mu_0)$	8.85×10^{-12} C ² /N·m ²	$8.854187817 \dots \times 10^{-12}$ C ² /N·m ²
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ T·m/A	$1.2566370614 \dots \times 10^{-6}$ T·m/A
Planck's constant	h	6.63×10^{-34} J·s	$6.6260693(11) \times 10^{-34}$ J·s
Electron rest mass	m_e	9.11×10^{-31} kg = 0.000549 u = 0.511 MeV/c ²	$9.1093826(16) \times 10^{-31}$ kg = $5.4857990945(24) \times 10^{-4}$ u
Proton rest mass	m_p	1.6726×10^{-27} kg = 1.00728 u = 938.3 MeV/c ²	$1.67262171(29) \times 10^{-27}$ kg = $1.00727646688(13)$ u
Neutron rest mass	m_n	1.6749×10^{-27} kg = 1.008665 u = 939.6 MeV/c ²	$1.67492728(29) \times 10^{-27}$ kg = $1.00866491560(55)$ u
Atomic mass unit (1 u)		1.6605×10^{-27} kg = 931.5 MeV/c ²	$1.66053886(28) \times 10^{-27}$ kg = $931.494043(80)$ MeV/c ²

[†] CODATA (12/03), Peter J. Mohr and Barry N. Taylor, National Institute of Standards and Technology. Numbers in parentheses indicate one-standard-deviation experimental uncertainties in final digits. Values without parentheses are exact (i.e., defined quantities).

Other Useful Data

Joule equivalent (1 cal)	4.186 J
Absolute zero (0 K)	-273.15°C
Acceleration due to gravity at Earth's surface (avg.)	9.80 m/s ² (= g)
Speed of sound in air (20°C)	343 m/s
Density of air (dry)	1.29 kg/m ³
Earth: Mass	5.98×10^{24} kg
Radius (mean)	6.38×10^3 km
Moon: Mass	7.35×10^{22} kg
Radius (mean)	1.74×10^3 km
Sun: Mass	1.99×10^{30} kg
Radius (mean)	6.96×10^5 km
Earth-Sun distance (mean)	149.6×10^6 km
Earth-Moon distance (mean)	384×10^3 km

The Greek Alphabet

Alpha	A	α	Nu	N	ν
Beta	B	β	Xi	Ξ	ξ
Gamma	Γ	γ	Omicron	O	o
Delta	Δ	δ	Pi	Π	π
Epsilon	E	ϵ	Rho	P	ρ
Zeta	Z	ζ	Sigma	Σ	σ
Eta	H	η	Tau	T	τ
Theta	Θ	θ	Upsilon	Y	υ
Iota	I	ι	Phi	Φ	ϕ, φ
Kappa	K	κ	Chi	X	χ
Lambda	Λ	λ	Psi	Ψ	ψ
Mu	M	μ	Omega	Ω	ω

Values of Some Numbers

$\pi = 3.1415927$	$\sqrt{2} = 1.4142136$	$\ln 2 = 0.6931472$	$\log_{10} e = 0.4342945$
$e = 2.7182818$	$\sqrt{3} = 1.7320508$	$\ln 10 = 2.3025851$	$1 \text{ rad} = 57.2957795^\circ$

Mathematical Signs and Symbols

\propto	is proportional to	\leq	is less than or equal to
$=$	is equal to	\geq	is greater than or equal to
\approx	is approximately equal to	Σ	sum of
\neq	is not equal to	\bar{x}	average value of x
$>$	is greater than	Δx	change in x
\gg	is much greater than	$\Delta x \rightarrow 0$	Δx approaches zero
$<$	is less than	$n!$	$n(n-1)(n-2)\dots(1)$
\ll	is much less than		

Properties of Water

Density (4°C)	1.000 kg/m ³
Heat of fusion (0°C)	333 kJ/kg (80 kcal/kg)
Heat of vaporization (100°C)	2260 kJ/kg (539 kcal/kg)
Specific heat (15°C)	4186 J/kg·C° (1.00 kcal/kg·C°)
Index of refraction	1.33