Physics Reference Tables*

Contents:

Table A. Metric Prefixes

Factor		Prefix	Symbol
1 000 000 000 000 000 000 000 000	10^{24}	yotta	Y
1 000 000 000 000 000 000 000	10^{21}	zeta	Z
1 000 000 000 000 000 000	10^{18}	exa	E
1 000 000 000 000 000	10^{15}	peta	P
1 000 000 000 000	10^{12}	tera	T
1 000 000 000	10^{9}	giga	G
1 000 000	10^{6}	mega	M
1 000	10^{3}	kilo	k
100	10^{2}	hecto	h
10	10^{1}	deca	da
1	10^{0}	—	—
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	µ
0.000 000 001	10^{-9}	nano	n
0.000 000 000 001	10^{-12}	pico	p
0.000 000 000 000 001	10^{-15}	femto	f
0.000 000 000 000 000 001	10^{-18}	atto	a
0.000 000 000 000 000 000 001	10^{-21}	zepto	z
0.000 000 000 000 000 000 000 001	10^{-24}	yocto	y

* Data from various sources, including: The University of the State of New York, The State Education Department. Albany, NY, *Reference Tables for Physical Setting/Physics, 2006 Edition*.http://www.p12.nysed.gov/apda/reftable/physics-rt/physics06tbl.pdf, *SparkNotes: SAT Physics* website. http://www.sparknotes.com/testprep/books/sat2/physics/, and College Board: *Equations and Constants for AP Physics 1 and AP Physics 2*.

Table B. Physical Constants

Description	Symbol	Precise Value	Common Approximation
universal gravitational constant	G	$6.67384(80)\times10^{-11}\ \frac{\text{N·m}^2}{\text{kg}^2}$	$6.67\times10^{-11}\ \frac{\text{N·m}^2}{\text{kg}^2}$
acceleration due to gravity on Earth's surface	g	$9.7639\ \frac{\text{m}}{\text{s}^2}$ to $9.8337\frac{\text{m}}{\text{s}^2}$ average value at sea level is $9.80665\ \frac{\text{m}}{\text{s}^2}$	$9.8\ \frac{\text{m}}{\text{s}^2}$ or $10\ \frac{\text{m}}{\text{s}^2}$
speed of light in a vacuum	c	$299792458\ \frac{\text{m}}{\text{s}}$ *	$3.00\times10^{8}\ \frac{\text{m}}{\text{s}}$
elementary charge (proton or electron)	e	$\pm1.602176565(35)\times10^{-19}$ C	$\pm1.6\times10^{-19}$ C
1 coulomb (C)		$6.24150965(16)\times10^{18}$ elementary charges	6.24×10^{18} elementary charges
(electric) permittivity of a vacuum	ε_o	$8.85418782\times10^{-12}\ \frac{\text{A}^2\cdot\text{s}^4}{\text{kg}\cdot\text{m}^3}$	$8.85\times10^{-12}\ \frac{\text{A}^2\cdot\text{s}^4}{\text{kg}\cdot\text{m}^3}$
(magnetic) permeability of a vacuum	μ_o	$4\pi\times10^{-7}=1.25663706\times10^{-6}\ \frac{\text{T}\cdot\text{m}}{\text{A}}$	$1.26\times10^{-6}\ \frac{\text{T}\cdot\text{m}}{\text{A}}$
electrostatic constant	k	$\frac{1}{4\pi\varepsilon_o}=8.9875517873681764\times10^{9}\ \frac{\text{N·m}^2}{\text{C}^2}$ *	$9.0\times10^{9}\ \frac{\text{N·m}^2}{\text{C}^2}$
1 electron volt (eV)		$1.602176565(35)\times10^{-19}$ J	1.6×10^{-19} J
Planck's constant	h	$6.62606957(29)\times10^{-34}$ J·s	6.6×10^{-34} J·s
1 universal (atomic) mass unit (u)		$931494061(21)\ \text{MeV}/c^2$ $1.660538921(73)\times10^{-27}$ kg	$931\text{MeV}/c^2$ 1.66×10^{-27} kg
Avogadro's constant	N_A	$6.02214129(27)\times10^{23}\ \text{mol}^{-1}$	$6.02\times10^{23}\ \text{mol}^{-1}$
Boltzmann constant	k_B	$1.3806488(13)\times10^{-23}\ \frac{\text{J}}{\text{K}}$	$1.38\times10^{-23}\ \frac{\text{J}}{\text{K}}$
universal gas constant	R	$8.3144621(75)\ \frac{\text{J}}{\text{mol}\cdot\text{K}}$	$8.31\ \frac{\text{J}}{\text{mol}\cdot\text{K}}$
Rydberg constant	R_H	$\frac{m_e e^4}{8\varepsilon_o^2 h^3 c}=10973731.6\frac{1}{\text{m}}$	$1.1\times10^{7}\ \text{m}^{-1}$
standard atmospheric pressure at sea level		101 325 Pa ≡ 1.01325 bar*	100 000 Pa ≡ 1.0 bar
rest mass of an electron	m_e	$9.10938215(45)\times10^{-31}$ kg	9.11×10^{-31} kg
mass of a proton	m_p	$1.672621777(74)\times10^{-27}$ kg	1.67×10^{-27} kg
mass of a neutron	m_n	$1.674927351(74)\times10^{-27}$ kg	1.67×10^{-27} kg

*denotes an exact value (by definition)

Table C. Approximate Coëfficients of Friction

Substance	Static (μ_s)	Kinetic (μ_k)	Substance	Static (μ_s)	Kinetic (μ_k)
rubber on concrete (dry)	0.90	0.68	wood on wood (dry)	0.42	0.30
rubber on concrete (wet)		0.58	wood on wood (wet)	0.2	
rubber on asphalt (dry)	0.85	0.67	wood on metal	0.3	
rubber on asphalt (wet)		0.53	wood on brick	0.6	
rubber on ice		0.15	wood on concrete	0.62	
steel on ice	0.03	0.01	Teflon on Teflon	0.04	0.04
waxed ski on snow	0.14	0.05	Teflon on steel	0.04	0.04
aluminum on aluminum	1.2	1.4	graphite on steel	0.1	
cast iron on cast iron	1.1	0.15	leather on wood	0.3–0.4	
steel on steel	0.74	0.57	leather on metal (dry)	0.6	
copper on steel	0.53	0.36	leather on metal (wet)	0.4	
diamond on diamond	0.1		glass on glass	0.9–1.0	0.4
diamond on metal	0.1–0.15		metal on glass	0.5–0.7	

Table D. Quantities, Variables and Units				
Quantity	**Variable**	**MKS Unit Name**	**MKS Unit Symbol**	**S.I. Base Unit**
position	$\vec{\boldsymbol{x}}$ $\boldsymbol{x}$	meter*	m	m
distance/displacement, (length, height)	$d, \vec{\boldsymbol{d}}, (\ell, h)$	meter*	m	m
angle	θ	radian, degree	—, °	—
area	A	square meter	m^2	m^2
volume	V	cubic meter, liter	m^3, ℓ, L	m^3
time	t	second*	s	s
velocity	$\vec{\boldsymbol{v}}$	meter/second	$\frac{m}{s}$	$\frac{m}{s}$
speed of light	c			
angular velocity	$\vec{\boldsymbol{\omega}}$	radians/second	$\frac{1}{s}$	$\frac{1}{s}$
acceleration	$\vec{\boldsymbol{a}}$	meter/second ^{2}	$\frac{m}{s^2}$	$\frac{m}{s^2}$
acceleration due to gravity	$\vec{\boldsymbol{g}}$			
mass	m	kilogram*	kg	kg
force	$\vec{\boldsymbol{F}}$	newton	N	$\frac{kg\cdot m}{s^2}$
pressure	P	pascal	Pa	$\frac{kg}{m\cdot s^2}$
energy	E	joule	J	$\frac{kg\cdot m^2}{s^2}$
potential energy	U			
kinetic energy	K			
heat	Q			
work	W	newton-meter	N·m	$\frac{kg\cdot m^2}{s^2}$
torque	$\vec{\boldsymbol{\tau}}$	newton-meter	N·m	$\frac{kg\cdot m^2}{s^2}$
power	P	watt	W	$\frac{kg\cdot m^2}{s^3}$
momentum	$\vec{\boldsymbol{p}}$	newton-second	N·s	$\frac{kg\cdot m}{s}$
impulse	$\vec{\boldsymbol{J}}$			
moment of inertia	I	kilogram-meter^2	kg·m^2	kg·m^2
angular momentum	$\vec{\boldsymbol{L}}$	newton-meter-second	N·m·s	$\frac{kg\cdot m^2}{s}$
frequency	f	hertz	Hz	s^{-1}
wavelength	λ	meter	m	m
period	T	second	s	s
index of refraction	n	—	—	—
electric current	$\vec{\boldsymbol{I}}$	ampere*	A	A
electric charge	q	coulomb	C	A·s
potential difference (voltage) electromotive force (emf)	V ε	volt	V	$\frac{kg\cdot m^2}{A\cdot s^3}$
electrical resistance	R	ohm	Ω	$\frac{kg\cdot m^2}{A^2\cdot s^3}$
capacitance	C	farad	F	$\frac{A^2\cdot s^4}{m^2\cdot kg}$
electric field	$\vec{\boldsymbol{E}}$	netwon/coulomb volt/meter	$\frac{N}{C}$, $\frac{V}{m}$	$\frac{kg\cdot m}{A\cdot s^3}$
magnetic field	$\vec{\boldsymbol{B}}$	tesla	T	$\frac{kg}{A\cdot s^2}$
temperature	T	kelvin*	K	K
amount of substance	n	mole*	mol	mol
luminous intensity	I_v	candela*	cd	cd

Variables representing vector quantities are typeset in ***bold italics***. * = S.I. base unit

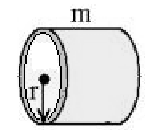
Table E. Mechanics Formulas and Equations

Kinematics (Distance, Velocity & Acceler-ation)	$\vec{d} = \Delta\vec{x} = \vec{x} - \vec{x}_o$ $\bar{\vec{v}} = \frac{\vec{d}}{t} = \frac{\Delta\vec{x}}{\Delta t} = \frac{\vec{v}_o + \vec{v}}{2}$ $\Delta\vec{v} = \vec{v} - \vec{v}_o = \vec{a}t$ $\vec{x} - \vec{x}_o = \vec{d} = \vec{v}_o t + \frac{1}{2}\vec{a}t^2$ $\vec{v}^2 - \vec{v}_o^2 = 2\vec{a}d$
Circular Motion	$s = r\Delta\theta$ $\quad \vec{v}_T = r\vec{\omega}$ $\quad \vec{a}_T = r\vec{\alpha}$ $a_c = \frac{v^2}{r} = \omega^2 r$ $\theta - \theta_0 = \vec{\omega}_0 t + \frac{1}{2}\vec{\alpha}t^2$
Forces & Dynamics	$\sum\vec{F} = \vec{F}_{net} = m\vec{a}$ $\quad \vec{F}_g = m\vec{g}$ $F_f \le \mu_s F_N$ $\quad F_f = \mu_k F_N$ $\vec{F}_g = \frac{Gm_1 m_2}{r^2}$
Rotational Dynamics	$x_{cm} = \frac{\sum m_i x_i}{\sum m_i}$ $I = \int_0^m r^2 dm = mr^2$ $F_c = ma_c = \frac{mv^2}{r}$ $\vec{\tau} = \vec{r} \times \vec{F}$ $\quad \tau = rF\sin\theta = r_\perp F$ $\sum\vec{\tau} = \vec{\tau}_{net} = I\vec{\alpha}$
Simple Harmonic Motion	$T = \frac{2\pi}{\omega} = \frac{1}{f}$ $T_s = 2\pi\sqrt{\frac{m}{k}}$ $\quad T_p = 2\pi\sqrt{\frac{L}{g}}$ $\vec{F}_s = -k\vec{x}$ $U_s = \frac{1}{2}kx^2$
Momentum	$\vec{p} = m\vec{v}$ $\Sigma m_i \vec{v}_i = \Sigma m_f \vec{v}_f$ $\vec{J} = \Delta\vec{p} = \vec{F}_{net}\Delta t$ $\vec{L} = \vec{r} \times \vec{p} = I\vec{\omega}$ $\quad L = rp\sin\theta = I\omega$ $\Delta\vec{L} = \vec{\tau}\Delta t$
Energy, Work & Power	$W = \vec{F} \bullet \vec{d} = Fd\cos\theta = F_{\parallel}d$ $W = \tau\Delta\theta$ $U_g = mgh = \frac{Gm_1 m_2}{r}$ $K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ $K = \frac{1}{2}I\omega^2$ $E_{total} = U + E_k + Q$ $W = \Delta K + \Delta U$ $P = \frac{W}{t} = \vec{F} \bullet \vec{v} = Fv\cos\theta = \tau\omega$

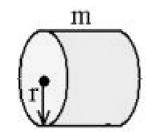
- Δ = change, difference
- Σ = sum
- d = distance (m)
- $\vec{d}$ = displacement (m)
- $\vec{x}$ = position (m)
- s = arc length (m)
- t = time (s)
- $\vec{v}$ = velocity $\left(\frac{\text{m}}{\text{s}}\right)$
- $\bar{\vec{v}}$ = average velocity $\left(\frac{\text{m}}{\text{s}}\right)$
- $\vec{a}$ = acceleration $\left(\frac{\text{m}}{\text{s}^2}\right)$
- f = frequency $\left(\text{Hz} = \frac{1}{\text{s}}\right)$
- a_c = centripetal acceleration $\left(\frac{\text{m}}{\text{s}^2}\right)$
- $\vec{F}$ = force (N)
- F_f = force due to friction (N)
- $\vec{F}_g$ = force due to gravity (N)
- F_N = normal force (N)
- F_c = centripetal force (N)
- m = mass (kg)
- $\vec{g}$ = acceleration due to gravity $\left(\frac{\text{m}}{\text{s}^2}\right)$
- G = gravitational constant $\left(\frac{\text{N}\cdot\text{m}^2}{\text{kg}^2}\right)$
- r = radius (m)
- $\vec{r}$ = radius (vector)
- μ = coefficient of friction (*dimensionless*)
- θ = angle (°, rad)
- ω = angular velocity $\left(\frac{\text{rad}}{\text{s}}\right)$
- k = spring constant $\left(\frac{\text{N}}{\text{m}}\right)$
- $\vec{x}$ = displacement of spring (m)
- L = length of pendulum (m)
- $\vec{\tau}$ = torque (N·m)
- K = kinetic energy (J)
- U = potential energy (J)
- h = height (m)
- Q = heat (J)
- P = power (W)
- W = work (N·m)
- T = (time) period (Hz)
- $\vec{p}$ = momentum (N·s)
- $\vec{J}$ = impulse (N·s)
- $\vec{L}$ = angular momentum (N·m·s)

Table F. Moments of Inertia

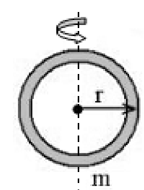
Point Mass:
$I = mr^2$



Hollow Cylinder:
$I = mr^2$

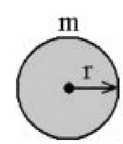


Solid Cylinder:
$I = \frac{1}{2}mr^2$

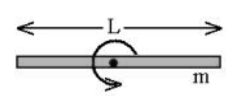


Hoop About Diameter:
$I = \frac{1}{2}mr^2$

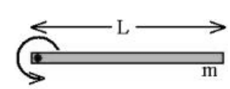
Hollow Sphere:
$I = \frac{2}{3}mr^2$



Solid Sphere:
$I = \frac{2}{5}mr^2$



Rod About the Middle:
$I = \frac{1}{12}mL^2$



Rod About the End:
$I = \frac{1}{3}mL^2$

Table G. Heat and Thermal Physics Formulas and Equations

Temperature	$°F = 1.8(°C) + 32$ $K = °C + 273.15$
Heat	$Q = mC\,\Delta T$ $Q_{melt} = m\Delta H_{fus}$ $Q_{boil} = m\Delta H_{vap}$ $C_p - C_v = R$ $\Delta L = \alpha L_i \Delta T$ $\Delta V = \beta V_i \Delta T$ $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $\frac{Q}{\Delta t} = kA\frac{\Delta T}{L}$ $\frac{Q}{t} = -\frac{1}{R_i} A\Delta T$
Thermodynamics	$\Delta U = \Delta Q + \Delta W$ $K = \frac{3}{2}k_B T$ $\Delta U = \frac{3}{2}Nk_B\Delta T = \frac{3}{2}nR\Delta T$ $W = -\Delta(PV)$

Δ = change
$°F$ = Fahrenheit temperature (°F)
$°C$ = Celsius temperature (°C)
K = Kelvin temperature (K)
Q = heat (J, kJ)
m = mass (kg)
C = specific heat capacity $\left(\frac{kJ}{kg\cdot°C}\right)$ (C_p = const. pressure; C_v = const. volume)
T = temperature (K)
t = time (s)
L = length (m)
k = coëfficient of thermal conductivity $\left(\frac{J}{m\cdot s\cdot°C}, \frac{W}{m\cdot°C}\right)$
V = volume (m^3)
α = linear coëfficient of thermal expansion ($°C^{-1}$)
β = volumetric coëfficient of thermal expansion ($°C^{-1}$)
R_i = "R" value of insulation
R = gas constant $\left(\frac{J}{mol\cdot K}\right)$
U = internal energy (J)
W = work (N·m)

Table H. Thermal Properties of Selected Materials

Substance	Melting Point (°C)	Boiling Point (°C)	Heat of Fusion ΔH_{fus} $\left(\frac{kJ}{kg}\right)$	Heat of Vaporization ΔH_{vap} $\left(\frac{kJ}{kg}\right)$	Specific Heat Capacity C_p $\left(\frac{kJ}{kg\cdot°C}\right)$ at 25°C	Thermal Conductivity k $\left(\frac{J}{m\cdot s\cdot°C}\right)$ at 25°C	Coefficients of Expansion at 20°C	
							Linear α ($°C^{-1}$)	Volumetric β ($°C^{-1}$)
air (gas)	—	—	—	—	1.012	0.024	—	—
aluminum (solid)	659	2467	395	10460	0.897	250	2.3×10^{-5}	6.9×10^{-5}
ammonia (gas)	−75	−33.3	339	1369	4.7	0.024	—	—
argon (gas)	−189	−186	29.5	161	0.520	0.016	—	—
carbon dioxide (gas)	−78		574		0.839	0.0146	—	—
copper (solid)	1086	1187	134	5063	0.385	401	1.7×10^{-5}	5.1×10^{-5}
brass (solid)	—	—	—	—	0.380	120	1.9×10^{-5}	5.6×10^{-5}
diamond (solid)	3550	4827	10 000	30 000	0.509	2200	1×10^{-6}	3×10^{-6}
ethanol (liquid)	−117	78	104	858	2.44	0.171	2.5×10^{-4}	7.5×10^{-4}
glass (solid)	—	—	—	—	0.84	0.96–1.05	8.5×10^{-6}	2.55×10^{-5}
gold (solid)	1063	2660	64.4	1577	0.129	310	1.4×10^{-5}	4.2×10^{-5}
granite (solid)	1240	—	—	—	0.790	1.7–4.0		
helium (gas)	—	−269	—	21	5.193	0.142	—	—
hydrogen (gas)	−259	−253	58.6	452	14.30	0.168	—	—
iron (solid)	1535	2750	289	6360	0.450	80	1.18×10^{-5}	3.33×10^{-5}
lead (solid)	327	1750	24.7	870	0.160	35	2.9×10^{-5}	8.7×10^{-5}
mercury (liquid)	−39	357	11.3	293	0.140	8	6.1×10^{-5}	1.82×10^{-4}
paraffin wax (solid)	46–68	~300	~210	—	2.5	0.25	—	—
silver (solid)	962	2212	111	2360	0.233	429	1.8×10^{-5}	5.4×10^{-5}
steam (gas) @			—	2260	2.080	0.016	—	—
water (liq.) @ 25°C	0	100	334		4.181	0.58	6.9×10^{-5}	2.07×10^{-4}
ice (solid) @ −10°C				—	2.11	2.18	—	—

<table>
<tr><th colspan="3">Table I. Electricity Formulas & Equations</th></tr>
<tr>
<td>Electrostatic Charges & Electric Fields</td>
<td>
$$\vec{F}_e = \frac{kq_1q_2}{r^2} = \frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r^2}$$
$$\vec{E} = \frac{\vec{F}_e}{q} = \frac{Q}{\varepsilon_o A} \qquad \vec{E} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2} = \frac{\Delta V}{\Delta r}$$
$$W = q\vec{E}\bullet\vec{d} = qEd\cos\theta$$
$$V = \frac{W}{q} = \vec{E}\bullet\vec{d} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r}$$
$$\Delta U_E = q\Delta V \qquad U_E = \frac{kq_1q_2}{r}$$
</td>
<td rowspan="4">
Δ = change
$\vec{F}_e$ = force due to electric field (N)
k = electrostatic constant $\left(\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)$
q = point charge (C)
Q = charge (C)
$\vec{E}$ = electric field $\left(\frac{\text{N}}{\text{C}}, \frac{\text{V}}{\text{m}}\right)$
V = voltage = electric potential difference (V)
W = work (N·m)
d = distance (m)
r = radius (m)
$\vec{I}$ = current (A)
t = time (s)
R = resistance (Ω)
P = power (W)
Q_H = heat (J)
ρ = resistivity ($\Omega\cdot$m)
ℓ = length (m)
A = cross-sectional area (m^2)
ε_o = electric permittivity of free space
U = potential energy (J)
C = capacitance (F)
$\vec{v}$ = velocity (of moving charge or wire) $\left(\frac{\text{m}}{\text{s}}\right)$
$\vec{B}$ = magnetic field (T)
μ_o = magnetic permeability of free space
r = radius (distance) from wire
</td>
</tr>
<tr>
<td>Circuits</td>
<td>
$$I = \frac{\Delta Q}{\Delta t} = \frac{V}{R} \qquad V = IR$$
$$P = VI = I^2R = \frac{V^2}{R}$$
$$W = Q_H = Pt = VIt = I^2Rt = \frac{V^2t}{R}$$
$$R = \frac{\rho\ell}{A}$$
$$V = \frac{Q}{C}$$
$$C = k\varepsilon_o\frac{A}{d}$$
$$U_{capacitor} = \frac{1}{2}QV = \frac{1}{2}CV^2$$
</td>
</tr>
<tr>
<td>Series Circuits</td>
<td>
$$I = I_1 = I_2 = I_3 = \ldots$$
$$V = V_1 + V_2 + V_3 + \ldots = \sum V_i$$
$$R_{eq} = R_1 + R_2 + R_3 + \ldots = \sum R_i$$
$$\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots = \sum\frac{1}{C_i}$$
$$P_{total} = P_1 + P_2 + P_3 + \ldots = \sum P_i$$
</td>
</tr>
<tr>
<td>Parallel Circuits</td>
<td>
$$I = I_1 + I_2 + I_3 + \ldots = \sum I_i$$
$$V = V_1 = V_2 = V_3 = \ldots$$
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots = \sum\frac{1}{R_i}$$
$$C_{total} = C_1 + C_2 + C_3 + \ldots = \sum C_i$$
$$P_{total} = P_1 + P_2 + P_3 + \ldots = \sum P_i$$
</td>
</tr>
</table>

Table J. Electricity & Magnetism Formulas & Equations

Magnetism	$\vec{F}_M = q\,(\vec{v}\times\vec{B})$ $F_M = q\,vB\sin\theta$ $\vec{F}_M = \ell(\vec{I}\times\vec{B})$ $F_M = \ell\,I\,B\sin\theta$ $V = \ell(\vec{v}\times\vec{B})$ $V = \ell vB\sin\theta$ $B = \frac{\mu_o}{2\pi}\frac{I}{r}$ $\Phi_B = \vec{B}\bullet\vec{A} = BA\cos\theta$ $\varepsilon = \frac{\Delta\Phi_B}{\Delta t} = B\ell v$
Electromagnetic Induction	$\frac{\#turns_{in}}{\#turns_{out}} = \frac{V_{in}}{V_{out}} = \frac{I_{out}}{I_{in}}$ $P_{in} = P_{out}$

Δ = change
$\vec{F}_M$ = force due to magnetic field (N)
k = electrostatic constant $\left(\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)$
q = point charge (C)
V = voltage = electric potential difference (V)
ε = emf = electromotive force (V)
r = radius (m)
$\vec{I}$ = current (A)
ℓ = length (m)
t = time (s)
A = cross-sectional area (m^2)
$\vec{v}$ = velocity (of moving charge or wire) $\left(\frac{\text{m}}{\text{s}}\right)$
$\vec{B}$ = magnetic field (T)
μ_o = magnetic permeability of free space
Φ_B = magnetic flux

Table K. Resistor Color Code

Color	Digit	Multiplier
black	0	$\times 10^0$
brown	1	$\times 10^1$
red	2	$\times 10^2$
orange	3	$\times 10^3$
yellow	4	$\times 10^4$
green	5	$\times 10^5$
blue	6	$\times 10^6$
violet	7	$\times 10^7$
gray	8	$\times 10^8$
white	9	$\times 10^9$
gold		± 5%
silver		± 10%

Table L. Symbols Used in Electrical Circuit Diagrams

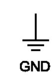
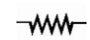
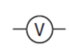
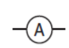
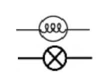
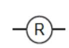
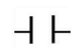
Component	Symbol	Component	Symbol
wire	—	battery	
switch		ground	
fuse		resistor	
voltmeter		variable resistor (rheostat, potentiometer, dimmer)	
ammeter		lamp (light bulb)	
ohmmeter		capacitor	
		diode	

Table M. Resistivities at 20°C

Conductors		Semiconductors		Insulators	
Substance	**Resistivity $(\Omega\cdot\text{m})$**	**Substance**	**Resistivity $(\Omega\cdot\text{m})$**	**Substance**	**Resistivity $(\Omega\cdot\text{m})$**
silver	1.59×10^{-8}	germanium	0.001 to 0.5	deionized water	1.8×10^{5}
copper	1.72×10^{-8}	silicon	0.1 to 60	glass	1×10^{9} to 1×10^{13}
gold	2.44×10^{-8}	sea water	0.2	rubber, hard	1×10^{13} to 1×10^{13}
aluminum	2.82×10^{-8}	drinking water	20 to 2 000	paraffin (wax)	1×10^{13} to 1×10^{17}
tungsten	5.60×10^{-8}			air	1.3×10^{16} to 3.3×10^{16}
iron	9.71×10^{-8}			quartz, fused	7.5×10^{17}
nichrome	1.50×10^{-6}				
graphite	3×10^{-5} to 6×10^{-4}				

Table N. Waves & Optics

Waves	$\lambda = \frac{v}{f}$ $f = \frac{1}{T}$ $v_{\text{wave on a string}} = \sqrt{\frac{F_T}{\mu}}$ $f_{\text{doppler shifted}} = f\left(\frac{v_{\text{wave}} + v_{\text{detector}}}{v_{\text{wave}} + v_{\text{source}}}\right)$	v = velocity of wave $\left(\frac{\text{m}}{\text{s}}\right)$ f = frequency (Hz) λ = wavelength (m) T = period (of time) (s) F_T = tension (force) on string (N) μ = elastic modulus of string $\left(\frac{\text{kg}}{\text{m}}\right)$ θ_i = angle of incidence (°, rad) θ_r = angle of reflection (°, rad) θ_c = critical angle (°, rad) n = index of refraction (*dimensionless*) c = speed of light in a vacuum $\left(\frac{\text{m}}{\text{s}}\right)$ s_f = distance to the focus of a mirror or lens (m) r_c = radius of curvature of a spherical mirror (m) s_i = distance from the mirror or lens to the image (m) s_o = distance from the mirror or lens to the object (m) h_i = height of the image (m) h_o = height of the object (m) M = magnification (*dimensionless*) d = separation (m) L = distance from the opening (m) m = an integer
Reflection, Refraction & Diffraction	$\theta_i = \theta_r$ $n = \frac{c}{v}$ $n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$ $\frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$ $\Delta L = m\lambda = d\sin\theta$	
Mirrors & Lenses	$s_f = \frac{r_c}{2}$ $\frac{1}{s_i} + \frac{1}{s_o} = \frac{1}{s_f}$ $M = \frac{h_i}{h_o} = -\frac{s_i}{s_o}$	

Figure O. The Electcromagnetic Spectrum

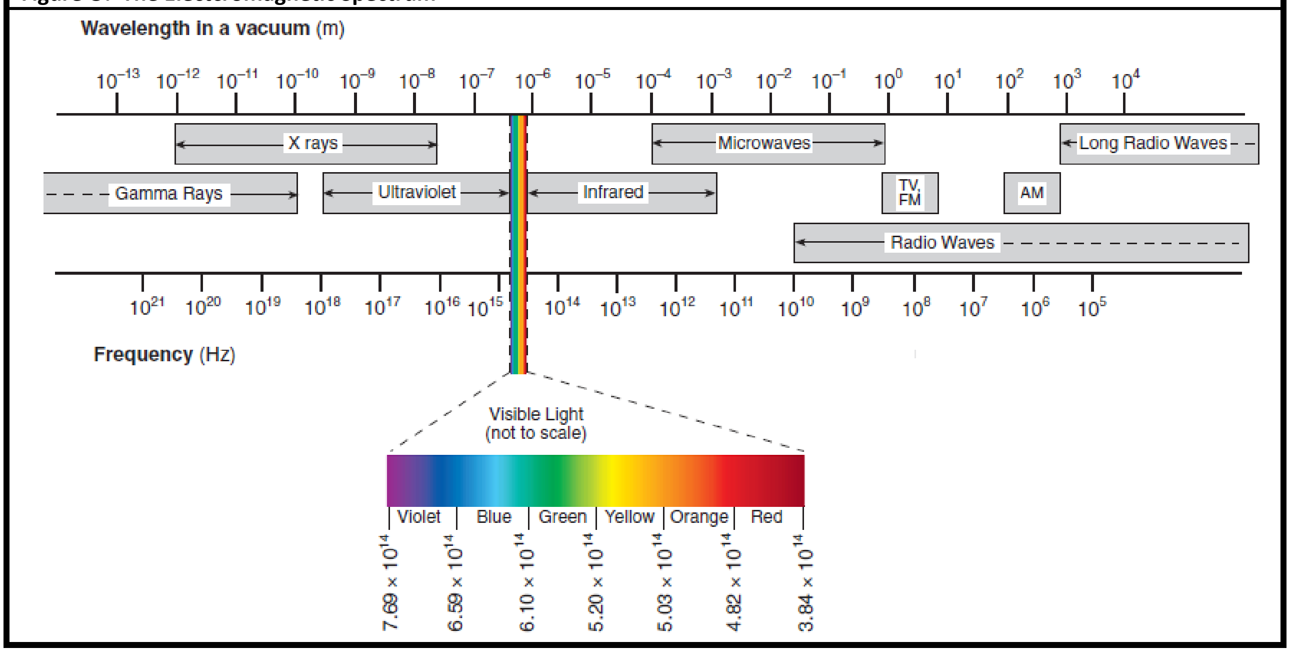


Table P. Properties of Water and Air

Temp. (°C)	Water: Density $\left(\frac{kg}{m^3}\right)$	Water: Speed of Sound $\left(\frac{m}{s}\right)$	Water: Vapor Pressure (Pa)	Air: Density $\left(\frac{kg}{m^3}\right)$	Air: Speed of Sound $\left(\frac{m}{s}\right)$
0	999.78	1 403	611.73	1.288	331.30
5	999.94	1 427	872.60	1.265	334.32
10	999.69	1 447	1 228.1	1.243	337.31
20	998.19	1 481	2 338.8	1.200	343.22
25	997.02	1 496	3 169.1	1.180	346.13
30	995.61	1 507	4 245.5	1.161	349.02
40	992.17	1 526	7 381.4	1.124	354.73
50	990.17	1 541	9 589.8	1.089	360.35
60	983.16	1 552	19 932	1.056	365.88
70	980.53	1 555	25 022	1.025	371.33
80	971.79	1 555	47 373	0.996	376.71
90	965.33	1 550	70 117	0.969	382.00
100	954.75	1 543	101 325	0.943	387.23

Table Q. Absolute Indices of Refraction

Measured at $f = 5.09 \times 10^{14}$ Hz (yellow light)

Substance	Index of Refraction	Substance	Index of Refraction
air	1.000293	silica (quartz), fused	1.459
ice	1.309	plexiglass	1.488
water	1.3330	Lucite	1.495
ethyl alcohol	1.36	glass, borosilicate (Pyrex)	1.474
human eye, cornea	1.38	glass, crown	1.50–1.54
human eye, lens	1.41	glass, flint	1.569–1.805
safflower oil	1.466	sodium chloride, solid	1.516
corn oil	1.47	PET (#1 plastic)	1.575
glycerol	1.473	zircon	1.777–1.987
honey	1.484–1.504	cubic zirconia	2.173–2.21
silicone oil	1.52	diamond	2.417
carbon disulfide	1.628	silicon	3.96

Table R. Fluid Mechanics Formulas and Equations

Density & Pressure	$\rho = \frac{m}{V}$ $P = \frac{F}{A}$ $\frac{F_1}{A_1} = \frac{F_2}{A_2}$ $P = P_o + \rho g h$ $A_1 v_1 = A_2 v_2$ $P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$	$\Delta =$ change $\rho =$ density $\left(\frac{\text{kg}}{\text{m}^3}\right)$ $m =$ mass (kg) $V =$ volume (m^3) $P =$ presure (Pa) $g =$ acceleration due to gravity $\left(\frac{\text{m}}{\text{s}^2}\right)$ $h =$ height or depth (m) $A =$ area (m^2) $v =$ velocity (of fluid) $\left(\frac{\text{m}}{\text{s}}\right)$ $F =$ force (N) $n =$ number of moles (mol) $R =$ gas constant $\left(\frac{\text{J}}{\text{mol·K}}\right)$ $N =$ number of molecules $k_B =$ Boltzmann's constant $\left(\frac{\text{J}}{\text{K}}\right)$ $T =$ temperature (K) $M =$ molar mass $\left(\frac{\text{g}}{\text{mol}}\right)$ $\mu =$ molecular mass (kg) $E_k =$ kinetic energy (J) $W =$ work (N·m)
Forces, Work & Energy	$F_B = \rho V_d g$ $PV = Nk_B T = nRT$ $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ $E_{k\,(molecular)} = \frac{3}{2} k_B T$ $v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_B T}{\mu}}$ $W = -P\Delta V$	

Table S. Planetary Data

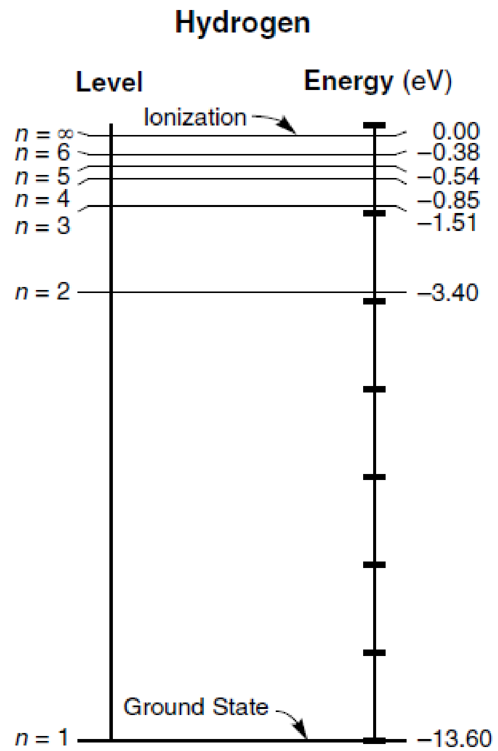
	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Distance from Sun (m)	5.79×10^{10}	1.08×10^{11}	1.50×10^{11}	2.28×10^{11}	7.78×10^{11}	1.43×10^{12}	2.87×10^{12}	4.50×10^{12}
Radius (m)	2.44×10^{6}	6.05×10^{6}	6.37×10^{6}	3.39×10^{6}	6.99×10^{7}	5.82×10^{7}	2.54×10^{7}	2.46×10^{7}
Mass (kg)	3.30×10^{23}	4.87×10^{24}	5.97×10^{24}	6.42×10^{23}	1.90×10^{27}	5.68×10^{26}	8.68×10^{25}	1.02×10^{26}
Density $\left(\frac{\text{kg}}{\text{m}^3}\right)$	5430	5250	5520	3950	1330	690	1290	1640
Orbit (years)	0.24	0.62	1.00	1.88	11.86	84.01	164.79	248.54
Rotation Period (hours)	1408	5832	23.9	24.6	9.9	10.7	17.2	16.1
Tilt of axis	2°	177.3°	23.5°	25.2°	3.1°	26.7°	97.9°	29.6°
# of observed satellites	0	0	1	2	67	62	27	13

Table T. Sun & Moon Data

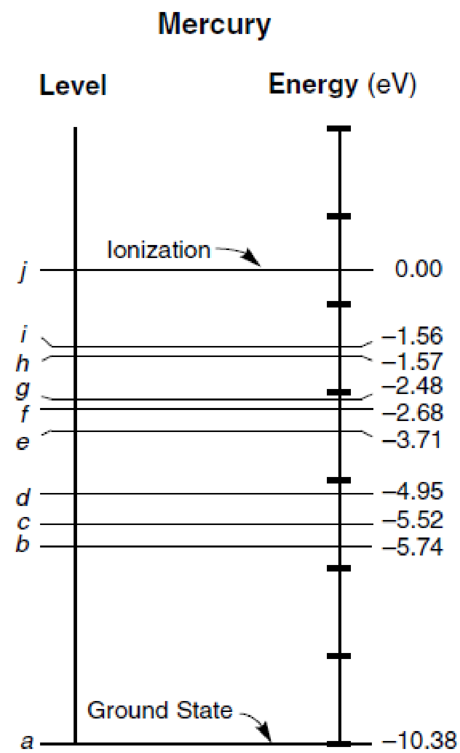
Radius of the sun (m)	6.96×10^{8}
Mass of the sun (kg)	1.99×10^{30}
Radius of the moon (m)	1.74×10^{6}
Mass of the moon (kg)	7.35×10^{22}
Distance of moon from Earth (m)	3.84×10^{8}

<table>
<tr><th colspan="3">Table U. Atomic & Particle Physics (Modern Physics)</th></tr>
<tr><td>Energy</td><td>$E_{photon} = hf = \frac{hc}{\lambda} = pc = \hbar\omega$
$E_{k,\max} = hf - \phi$
$\lambda = \frac{h}{p}$
$E_{photon} = E_i - E_f$
$E^2 = (pc)^2 + (mc^2)^2$
$\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$</td><td rowspan="2">$E$ = energy (J)
h = Planck's constant (J·s)
$\hbar$ = reduced Planck's constant= $\frac{h}{2\pi}$ (J·s)
f = frequency (Hz)
c = speed of light $\left(\frac{\text{m}}{\text{s}}\right)$
λ = wavelength (m)
p = momentum (N·s)
m = mass (kg)
E_k = kinetic energy (J)
ϕ = work function
R_H = Rydberg constant$\left(\frac{1}{\text{m}}\right)$
γ = Lorentz factor (dimensionless)
L = length in moving reference frame (m)
L_o = length in stationary reference frame (m)
$\Delta t'$ = time in stationary reference frame (s)
Δt = time in moving reference frame (s)
m_o = mass in stationary reference frame (kg)
m_{rel} = apparent mass in moving reference frame (kg)
v = velocity $\left(\frac{\text{m}}{\text{s}}\right)$</td></tr>
<tr><td>Special Relativity</td><td>$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$
$\gamma = \frac{L_o}{L}$
$\gamma = \frac{\Delta t'}{\Delta t}$
$\gamma = \frac{m_{rel}}{m_o}$</td></tr>
</table>

Figure V. Quantum Energy Levels



Energy Levels for the Hydrogen Atom



A Few Energy Levels for the Mercury Atom

Figure W. Particle Sizes

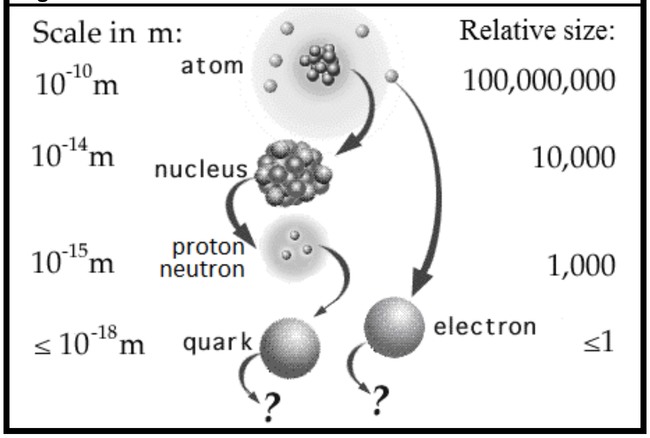
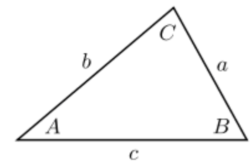


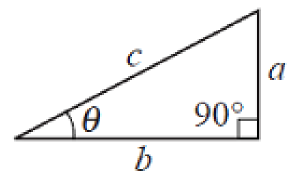
Table X. The Standard Model

	Generation I	Generation II	Generation III		
mass → charge → spin → **quarks**	2.4 MeV/c² +⅔ ½ **u** up quark	1.27 GeV/c² +⅔ ½ **c** charm quark	171.2 GeV/c² +⅔ ½ **t** top quark	0 MeV/c² 0 1 **γ** photon	125.3 GeV/c² 0 0 **H^0** Higgs boson
quarks	4.8 MeV/c² −⅓ ½ **d** down quark	104 MeV/c² −⅓ ½ **s** strange quark	4.2 GeV/c² −⅓ ½ **b** bottom quark	0 MeV/c² 0 1 **g** gluon	
leptons	< 2.2 eV/c² 0 ½ **ν_e** electron neutrino	< 0.17 MeV/c² 0 ½ **ν_μ** muon neutrino	< 15.5 MeV/c² 0 ½ **ν_τ** tau neutrino	91.2 GeV/c² 0 1 **Z^0** Z boson	**gauge bosons**
leptons	0.511 MeV/c² −1 ½ ***e*** electron	105.7 MeV/c² −1 ½ **μ** muon	1.777 GeV/c² −1 ½ **τ** tau	80.4 GeV/c² ±1 1 **$W^\pm$** W boson	**gauge bosons**

Table Y. Geometry & Trigonometry Formulas

Triangles	$A = \frac{1}{2}bh$ $c^2 = a^2 + b^2 - 2ab\cos C$ $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$
Right Triangles	$c^2 = a^2 + b^2$ $\sin\theta = \frac{a}{c} = \frac{\text{opposite}}{\text{hypotenuse}}$ $\cos\theta = \frac{b}{c} = \frac{\text{adjacent}}{\text{hypotenuse}}$ $\tan\theta = \frac{\sin\theta}{\cos\theta} = \frac{a}{b} = \frac{\text{opposite}}{\text{adjacent}}$ $b = c\cos\theta$ $a = c\sin\theta$
Rectangles, Parallelograms and Trapezoids	$A = \bar{b}h$
Rectangular Solids	$V = \ell wh$
Circles	$C = 2\pi r$ $A = \pi r^2$
Cylinders	$S = 2\pi r\ell + 2\pi r^2 = 2\pi r(\ell + r)$ $V = \pi r^2 \ell$
Spheres	$S = 4\pi r^2$ $V = \frac{4}{3}\pi r^3$





a, b, c = length of a side of a triangle
θ = angle
A = area
C = circumference
S = surface area
V = volume
b = base
h = height
ℓ = length
w = width
r = radius

Table Z. Values of Trigonometric Functions

degree	radian	sine	cosine	tangent	degree	radian	sine	cosine	tangent
0°	0.000	0.000	1.000	0.000					
1°	0.017	0.017	1.000	0.017	46°	0.803	0.719	0.695	1.036
2°	0.035	0.035	0.999	0.035	47°	0.820	0.731	0.682	1.072
3°	0.052	0.052	0.999	0.052	48°	0.838	0.743	0.669	1.111
4°	0.070	0.070	0.998	0.070	49°	0.855	0.755	0.656	1.150
5°	0.087	0.087	0.996	0.087	50°	0.873	0.766	0.643	1.192
6°	0.105	0.105	0.995	0.105	51°	0.890	0.777	0.629	1.235
7°	0.122	0.122	0.993	0.123	52°	0.908	0.788	0.616	1.280
8°	0.140	0.139	0.990	0.141	53°	0.925	0.799	0.602	1.327
9°	0.157	0.156	0.988	0.158	54°	0.942	0.809	0.588	1.376
10°	0.175	0.174	0.985	0.176	55°	0.960	0.819	0.574	1.428
11°	0.192	0.191	0.982	0.194	56°	0.977	0.829	0.559	1.483
12°	0.209	0.208	0.978	0.213	57°	0.995	0.839	0.545	1.540
13°	0.227	0.225	0.974	0.231	58°	1.012	0.848	0.530	1.600
14°	0.244	0.242	0.970	0.249	59°	1.030	0.857	0.515	1.664
15°	0.262	0.259	0.966	0.268	60°	1.047	0.866	0.500	1.732
16°	0.279	0.276	0.961	0.287	61°	1.065	0.875	0.485	1.804
17°	0.297	0.292	0.956	0.306	62°	1.082	0.883	0.469	1.881
18°	0.314	0.309	0.951	0.325	63°	1.100	0.891	0.454	1.963
19°	0.332	0.326	0.946	0.344	64°	1.117	0.899	0.438	2.050
20°	0.349	0.342	0.940	0.364	65°	1.134	0.906	0.423	2.145
21°	0.367	0.358	0.934	0.384	66°	1.152	0.914	0.407	2.246
22°	0.384	0.375	0.927	0.404	67°	1.169	0.921	0.391	2.356
23°	0.401	0.391	0.921	0.424	68°	1.187	0.927	0.375	2.475
24°	0.419	0.407	0.914	0.445	69°	1.204	0.934	0.358	2.605
25°	0.436	0.423	0.906	0.466	70°	1.222	0.940	0.342	2.747
26°	0.454	0.438	0.899	0.488	71°	1.239	0.946	0.326	2.904
27°	0.471	0.454	0.891	0.510	72°	1.257	0.951	0.309	3.078
28°	0.489	0.469	0.883	0.532	73°	1.274	0.956	0.292	3.271
29°	0.506	0.485	0.875	0.554	74°	1.292	0.961	0.276	3.487
30°	0.524	0.500	0.866	0.577	75°	1.309	0.966	0.259	3.732
31°	0.541	0.515	0.857	0.601	76°	1.326	0.970	0.242	4.011
32°	0.559	0.530	0.848	0.625	77°	1.344	0.974	0.225	4.331
33°	0.576	0.545	0.839	0.649	78°	1.361	0.978	0.208	4.705
34°	0.593	0.559	0.829	0.675	79°	1.379	0.982	0.191	5.145
35°	0.611	0.574	0.819	0.700	80°	1.396	0.985	0.174	5.671
36°	0.628	0.588	0.809	0.727	81°	1.414	0.988	0.156	6.314
37°	0.646	0.602	0.799	0.754	82°	1.431	0.990	0.139	7.115
38°	0.663	0.616	0.788	0.781	83°	1.449	0.993	0.122	8.144
39°	0.681	0.629	0.777	0.810	84°	1.466	0.995	0.105	9.514
40°	0.698	0.643	0.766	0.839	85°	1.484	0.996	0.087	11.430
41°	0.716	0.656	0.755	0.869	86°	1.501	0.998	0.070	14.301
42°	0.733	0.669	0.743	0.900	87°	1.518	0.999	0.052	19.081
43°	0.750	0.682	0.731	0.933	88°	1.536	0.999	0.035	28.636
44°	0.768	0.695	0.719	0.966	89°	1.553	1.000	0.017	57.290
45°	0.785	0.707	0.707	1.000	90°	1.571	1.000	0.000	∞

Table AA. Some Exact and Approximate Conversions

Length	1 cm	≈	width of a small paper clip		
	1 inch (in.)	≡	2.54 cm		
	length of a US dollar bill	=	6.14 in.	=	15.6 cm
	12 in.	≡	1 foot (ft.)	≈	30 cm
	3 ft.	≡	1 yard (yd.)	≈	1 m
	1 m	=	0.3048 ft.	=	39.37 in.
	1 km	≈	0.6 mi.		
	5,280 ft.	≡	1 mile (mi.)	≈	1.6 km
Mass/ Weight	1 small paper clip	≈	0.5 gram (g)		
	US 1¢ coin (1983–present)	=	2.5 g		
	US 5¢ coin	=	5 g		
	1 oz.	≈	30 g		
	one medium-sized apple	≈	1 N	≈	3.6 oz.
	1 pound (lb.)	≡	16 oz.	≈	454 g
	1 pound (lb.)	≈	4.45 N		
	1 ton	≡	2000 lb.	≈	0.9 tonne
	1 tonne	≡	1000 kg	≈	1.1 ton
Volume	1 pinch	=	≤ $^{1}/_{8}$ teaspoon (tsp.)		
	1 mL	≈	10 drops		
	1 tsp.	≈	5 mL	≈	60 drops
	3 tsp.	≡	1 tablespoon (Tbsp.)	≈	15 mL
	2 Tbsp.	≡	1 fluid ounce (fl. oz.)	≈	30 mL
	8 fl. oz.	≡	1 cup (C)	≈	250 mL
	16 fl. oz.	≡	1 U.S. pint (pt.)	≈	500 mL
	20 fl. oz.	≡	1 Imperial pint (UK)	≈	600 mL
	2 pt.	≡	1 U.S. quart (qt.)	≈	1 L
	4 qt. (U.S.)	≡	1 U.S. gallon (gal.)	≈	3.8 L
	4 qt. (UK) ≡ 5 qt. (U.S.)	≡	1 Imperial gal. (UK)	≈	4.7 L
Speed	1 $^{m}/_{s}$	≈	2.24 $^{mi.}/_{h}$		
	60 $^{mi.}/_{h}$	≈	100 $^{km}/_{h}$	≈	27 $^{m}/_{s}$
Energy	1 cal	≈	4.18 J		
	1 Calorie (food)	≡	1 kcal	≈	4.18 kJ
	1 BTU	≈	1.05 kJ		
Power	1 hp	≈	746 W		
	1 kW	≈	1.34 hp		
Temperature	0 K	≡	−273.15°C	=	absolute zero
	0°F	≈	−18°C		
	32°F	=	0°C = 273.15 K	=	water freezes
	70°F	≈	21°C	≈	room temperature
	212°F	=	100°C	=	water boils
Speed of light	300 000 000 $^{m}/_{s}$	≈	186 000 $^{mi.}/_{s}$	≈	1 $^{ft.}/_{ns}$

Table BB. Greek Alphabet

Α	α	alpha
Β	β	beta
Γ	γ	gamma
Δ	δ	delta
Ε	ε, ϵ	epsilon
Ζ	ζ	zeta
Η	η	eta
Θ	θ	theta
Ι	ι	iota
Κ	κ	kappa
Λ	λ	lambda
Μ	μ	mu
Ν	ν	nu
Ξ	ξ	xi
Ο	ο	omicron
Π	π	pi
Ρ	ρ	rho
Σ	σ	sigma
Τ	τ	tau
Υ	υ	upsilon
Φ	ϕ, φ	phi
Χ	χ	chi
Ψ	ψ	psi
Ω	ω	omega