Appendix: Physics Reference Tables

Contents:

Table A. Metric Prefixes

Factor		Prefix	Symbol
1 000 000 000 000 000 000 000 000 000 000	10^{30}	quetta	Q
1 000 000 000 000 000 000 000 000 000	10^{27}	ronna	R
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
0.000 000 000 000 000 000 000 000 001	10^{-27}	ronto	r
0.000 000 000 000 000 000 000 000 000 001	10^{-30}	quecto	q

↓ Move Decimal Point to the Right ↓

↑ Move Decimal Point to the Left ↑

Table B. Physical Constants			
Description	**Symbol**	**Precise Value**	**Common Approximation**
acceleration due to gravity on Earth strength of gravity field on Earth	g	$9.7639\ \frac{m}{s^2}$ to $9.8337\ \frac{m}{s^2}$ average value at sea level is $9.806\,65\ \frac{m}{s^2}$	$9.8\ \frac{m}{s^2} \equiv 9.8\ \frac{N}{kg}$ or $10\ \frac{m}{s^2} \equiv 10\ \frac{N}{kg}$
universal gravitational constant	G	$6.673\,84(80)\times10^{-11}\ \frac{N\cdot m^2}{kg^2}$	$6.67\times10^{-11}\ \frac{N\cdot m^2}{kg^2}$
speed of light in a vacuum	c	$299\,792\,458\ \frac{m}{s}$ *	$3.00\times10^{8}\ \frac{m}{s}$
elementary charge (proton or electron)	e	$\pm1.602\,176\,634\times10^{-19}$ C*	$\pm1.60\times10^{-19}$ C
1 coulomb (C)		$6.241\,509\,074\times10^{18}$ elementary charges	6.24×10^{18} elementary charges
(electric) permittivity of a vacuum	ε_o	$8.854\,187\,82\times10^{-12}\ \frac{A^2\cdot s^4}{kg\cdot m^3}$	$8.85\times10^{-12}\ \frac{A^2\cdot s^4}{kg\cdot m^3}$
(magnetic) permeability of a vacuum	μ_o	$4\pi\times10^{-7} = 1.256\,637\,06\times10^{-6}\ \frac{T\cdot m}{A}$	$1.26\times10^{-6}\ \frac{T\cdot m}{A}$
electrostatic constant	k	$\frac{1}{4\pi\varepsilon_o} = 8.987\,551\,787\,368\,176\,4\times10^{9}\ \frac{N\cdot m^2}{C^2}$ *	$8.99\times10^{9}\ \frac{N\cdot m^2}{C^2}$
1 electron volt (eV)		$1.602\,176\,565(35)\times10^{-19}$ J	1.60×10^{-19} J
Planck's constant	h	$6.626\,070\,15\times10^{-34}$ J·s*	6.63×10^{-34} J·s
1 universal (atomic) mass unit (u)		$931.494\,061(21)$ MeV/ c^2 $1.660\,538\,921(73)\times10^{-27}$ kg	931 MeV/c^2 1.66×10^{-27} kg
Avogadro's constant	N_A	$6.022\,140\,76\times10^{23}$ mol^{-1} *	6.02×10^{23} mol^{-1}
Boltzmann constant	k_B	$1.380\,649\times10^{-23}\ \frac{J}{K}$ *	$1.38\times10^{-23}\ \frac{J}{K}$
universal gas constant	R	$8.314\,4621(75)\ \frac{J}{mol\cdot K}$	$8.31\ \frac{J}{mol\cdot K}$
Rydberg constant	R_H	$\frac{m_e e^4}{8\varepsilon_o^2 h^3 c} = 10\,973\,731.6\ \frac{1}{m}$	1.10×10^{7} m^{-1}
Stefan-Boltzmann constant	σ	$\frac{2\pi^5 R^4}{15h^3c^2} = 5.670\,374\,419\times10^{-8}\ \frac{J}{m^2\cdot s\cdot K^4}$	$5.67\times10^{-8}\ \frac{J}{m^2\cdot s\cdot K^4}$
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	$9.109\,382\,15(45)\times10^{-31}$ kg	9.11×10^{-31} kg
mass of a proton	m_p	$1.672\,621\,777(74)\times10^{-27}$ kg	1.67×10^{-27} kg
mass of a neutron	m_n	$1.674\,927\,351(74)\times10^{-27}$ kg	1.67×10^{-27} kg

*denotes an exact value (by definition)

Table C. Quantities, Variables and Units

Quantity	Variable	MKS Unit Name	MKS Unit Symbol	S.I. Base Unit
position	$\vec{\boldsymbol{x}}$	meter*	m	m
distance/displacement, (length, height)	$d, \vec{\boldsymbol{d}}, (L, h)$	meter*	m	m
angle	θ	radian, degree	—, °	—
area	A	square meter	m^2	m^2
volume	V	cubic meter, liter	m^3	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	$\frac{1}{s^2}$, s^{-1}	$\frac{1}{s^2}$, s^{-1}
acceleration	$\vec{\boldsymbol{a}}$	meter/second^2	$\frac{m}{s^2}$	$\frac{m}{s^2}$
acceleration due to gravity	$\vec{\boldsymbol{g}}$			
angular acceleration	$\vec{\boldsymbol{\alpha}}$	radians/second^2	$\frac{1}{s^2}$, s^{-2}	$\frac{1}{s^2}$, s^{-2}
mass	m	kilogram*	kg	kg
force	$\vec{\boldsymbol{F}}$	newton	N	$\frac{kg \cdot m}{s^2}$
gravitational field	$\vec{\boldsymbol{g}}$	newton/kilogram	$\frac{N}{kg}$	$\frac{m}{s^2}$
pressure	P	pascal	Pa	$\frac{kg}{m \cdot s^2}$
energy (generic)	E	joule	J	$\frac{kg \cdot m^2}{s^2}$
potential energy	U			
kinetic energy	K, E_k			
heat	Q			
work	W	joule , newton-meter	J , 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
electric potential potential difference (voltage) electromotive force (emf)	V ΔV 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*** with ***arrows***. * = S.I. base unit

Table D. Mechanics Formulas and Equations

Kinematics (Distance, Velocity & Acceleration)	$\vec{d} = \Delta\vec{x} = \vec{x} - \vec{x}_o$ $\frac{\vec{d}}{t} = \frac{\vec{v}_o + \vec{v}}{2} (= \vec{v}_{ave.})$ $\vec{v} - \vec{v}_o = \vec{a}t$ $\vec{d} = \vec{v}_o t + \frac{1}{2}\vec{a}t^2$ $\vec{v}^2 - \vec{v}_o^2 = 2\vec{a}\vec{d}$
Forces & Dynamics	$\sum\vec{F} = \vec{F}_{net} = m\vec{a}$ $F_f \le \mu_s F_N \qquad F_f = \mu_k F_N$ $\vec{F}_g = m\vec{g} = \frac{Gm_1m_2}{r^2}$
Circular/ Centripetal Motion & Force	$a_c = \frac{v^2}{r}$ $F_c = ma_c$
Simple Harmonic Motion	$T = \frac{1}{f}$ $T_s = 2\pi\sqrt{\frac{m}{k}} \qquad T_p = 2\pi\sqrt{\frac{L}{g}}$ $\vec{F}_s = -k\vec{x}$ $U_s = \frac{1}{2}kx^2$
Energy, Work & Power	$U_g = mgh = \frac{Gm_1m_2}{r}$ $K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ $W = \Delta E = \Delta(U_g + K)$ $W = F_{\parallel}d = \vec{F}_{net} \bullet \vec{d} = Fd\cos\theta$ $TME = U_g + K$ $TME_i + W = TME_f$ $P = \frac{W}{t} = \vec{F} \bullet \vec{v} = Fv\cos\theta$
Momentum	$\vec{p} = \sum m\vec{v}$ $\Sigma m_i\vec{v}_i + \vec{J} = \Sigma m_f\vec{v}_f$ $\vec{J} = \Delta\vec{p} = \vec{F}_{net}t$

var. = name of quantity (unit)

- Δ = change in something (*E.g.,* Δx means change in x)
- Σ = sum
- d = distance (m)
- $\vec{d}$ = displacement (m)
- $\vec{x}$ = position (m)
- t = time (s)
- $\vec{v}$ = velocity $\left(\frac{\text{m}}{\text{s}}\right)$
- $\vec{v}_{ave.}$ = average velocity $\left(\frac{\text{m}}{\text{s}}\right)$
- $\vec{a}$ = acceleration $\left(\frac{\text{m}}{\text{s}^2}\right)$
- f = frequency $\left(\text{Hz} = \frac{1}{\text{s}}\right)$
- $\vec{F}$ = force (N)
- $\vec{F}_{net}$ = net force (N)
- F_f = force due to friction (N)
- $\vec{F}_g$ = force due to gravity (N)
- $\vec{F}_N$ = normal force (N)
- m = mass (kg)
- $\vec{g}$ = strength of gravity field = aceleration due to gravity $= 10\,\frac{\text{N}}{\text{kg}} = 10\,\frac{\text{m}}{\text{s}^2}$ on Earth
- G = gravitational constant $= 6.67 \times 10^{-11}\,\frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}$
- r = radius (m)
- μ = coëfficient of friction* (*dimensionless*)
- θ = angle (°, radians)
- k = spring constant $\left(\frac{\text{N}}{\text{m}}\right)$
- $\vec{x}$ = displacement of spring (m)
- L = length of pendulum (m)
- E = energy (J)
- $K = E_k$ = kinetic energy (J)
- U = potential energy (J)
- TME = total mechanical energy (J)
- h = height (m)
- Q = heat (J)
- P = power (W)
- W = work (J, N·m)
- T = (time) period (Hz)
- $\vec{p}$ = momentum (N·s)
- $\vec{J}$ = impulse (N·s)
- π = pi (mathematical constant) = 3.14159 26535 89793...

*characteristic property of a substance (to be looked up)

Table E. 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	

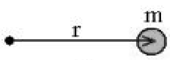
Table F. Angular/Rotational Mechanics Formulas and Equations

Angular Kinematics (Distance, Velocity & Acceleration)	$\Delta\vec{\boldsymbol{\theta}} = \vec{\boldsymbol{\theta}} - \vec{\boldsymbol{\theta}}_o$ $\frac{\Delta\vec{\boldsymbol{\theta}}}{t} = \frac{\vec{\boldsymbol{\omega}}_o + \vec{\boldsymbol{\omega}}}{2} (= \vec{\boldsymbol{\omega}}_{ave.})$ $\vec{\boldsymbol{\omega}} - \vec{\boldsymbol{\omega}}_o = \vec{\boldsymbol{\alpha}}t$ $\Delta\vec{\boldsymbol{\theta}} = \vec{\boldsymbol{\omega}}_o t + \frac{1}{2}\vec{\boldsymbol{\alpha}}t^2$ $\vec{\boldsymbol{\omega}}^2 - \vec{\boldsymbol{\omega}}_o^2 = 2\vec{\boldsymbol{\alpha}}(\Delta\vec{\boldsymbol{\theta}})$
Circular/ Centripetal Motion	$s = r\Delta\theta \quad v_T = r\omega \quad a_T = r\alpha$ $a_c = \frac{v^2}{r} = \omega^2 r$
Rotational Dynamics	$x_{cm} = \frac{\sum m_i x_i}{\sum m_i}$ $I = \_\_mr^2 = \int_0^m r^2 dm$ $F_c = ma_c = mr\omega^2$ $\vec{\boldsymbol{\tau}} = \vec{\boldsymbol{r}} \times \vec{\boldsymbol{F}} \quad \tau = rF\sin\theta = r_\perp F$ $\sum \vec{\boldsymbol{\tau}} = \vec{\boldsymbol{\tau}}_{net} = I\vec{\boldsymbol{\alpha}}$
Simple Harmonic Motion	$T = \frac{1}{f} = \frac{2\pi}{\omega}$ $x = A\cos(2\pi ft) + \phi$
Angular Momentum	$\vec{\boldsymbol{L}} = \vec{\boldsymbol{r}} \times \vec{\boldsymbol{p}} = I\vec{\boldsymbol{\omega}} \quad L = rp\sin\theta = I\omega$ $\Delta\vec{\boldsymbol{L}} = \vec{\boldsymbol{\tau}}\Delta t$
Angular/ Rotational Energy, Work & Power	$K_r = \frac{1}{2}I\omega^2$ $K = K_t + K_r = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$ $W_r = \tau\Delta\theta$ $P = \frac{W}{t} = \tau\omega$

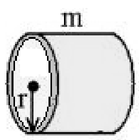
var. = name of quantity (unit)

- Δ = change in something (*E.g.,* Δx = change in x)
- Σ = sum
- s = arc length (m)
- t = time (s)
- a_c = centripetal acceleration $\left(\frac{\text{m}}{\text{s}^2}\right)$
- F_c = centripetal force (N)
- m = mass (kg)
- r = radius (m)
- $\vec{\boldsymbol{r}}$ = radius (vector)
- θ = angle (°, radians)
- $\vec{\boldsymbol{\omega}}$ = angular velocity $\left(\frac{\text{rad}}{\text{s}}\right)$
- $\vec{\boldsymbol{\alpha}}$ = angular velocity $\left(\frac{\text{rad}}{\text{s}^2}\right)$
- $\vec{\boldsymbol{\tau}}$ = torque (N·m)
- x = position (m)
- f = frequency (Hz)
- A = amplitude (m)
- ϕ = phase offset (°, rad)
- E = energy (J)
- $K = E_k$ = kinetic energy (J)
- K_t = translational kinetic energy (J)
- K_r = rotational kinetic energy (J)
- P = power (W)
- W = work (J, N·m)
- $\vec{\boldsymbol{p}}$ = momentum (N·s)
- $\vec{\boldsymbol{L}}$ = angular momentum (N·m·s)

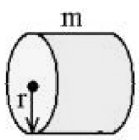
Table G. Moments of Inertia



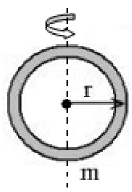
Point Mass: $I = mr^2$



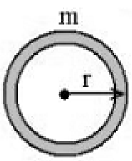
Hollow Cylinder: $I = mr^2$



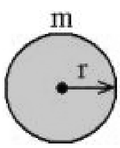
Solid Cylinder: $I = \frac{1}{2}mr^2$



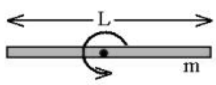
Hoop About Diameter: $I = \frac{1}{2}mr^2$



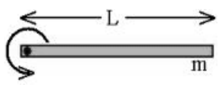
Hollow Sphere: $I = \frac{2}{3}mr^2$



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 H. Heat and Thermal Physics Formulas and Equations

Temperature	$T_{°F} = 1.8(T_{°C}) + 32$ $T_K = T_{°C} + 273.15$
Heat	$Q = mC\Delta T$ $Q_{melt} = m\Delta H_{fus}$ $Q_{boil} = m\Delta H_{vap}$ $C_p - C_v = R$ $\Delta L = \alpha L_i \Delta T$ $\Delta V = \beta V_i \Delta T$ $P = \frac{Q}{t} = (\pm)\, kA\frac{\Delta T}{L}$ $P = \frac{Q}{t} = \varepsilon\sigma A T^4$ (*in this section, P = power*)
Thermo-dynamics	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ $PV = nRT = Nk_BT$ $P\Delta V = nR\Delta T = Nk_B\Delta T$ $\Delta U = Q + W$ $U = \frac{3}{2}nRT \quad \Delta U = \frac{3}{2}nR\Delta T$ $W = -P\Delta V = -\int_{V_1}^{V_2} P\,dV$ $K_{(molecular)} = \frac{3}{2}RT$ $U = \frac{3}{2}nRT = \frac{3}{2}Nk_BT$ $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}Nk_B\Delta T$ $v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_BT}{\mu}}$ $\Delta S = \frac{Q_{rev}}{T} \geq \frac{Q}{T}$ $A = U - TS$ $\Delta A = \Delta U - T\Delta S$ (*in this section, P = pressure*)

var. = name of quantity (unit)

- Δ = change in something (*E.g.*, Δx = change in *x*)
- $T = T_K$ = Kelvin temperature (K)
- $T_{°F}$ = Fahrenheit temperature (°F)
- $T_{°C}$ = Celsius temperature (°C)
- Q = heat (J, kJ)
- m = mass (kg)
- C = specific heat capacity* $\left(\frac{kJ}{kg \cdot °C}, \frac{J}{g \cdot °C}\right)$
- t = time (s)
- L = length (m)
- k = coëfficient of thermal conductivity* $\left(\frac{J}{m \cdot s \cdot °C}, \frac{W}{m \cdot °C}\right)$
- ε = emissivity* (*dimensionless*)
- H_{fus} = latent heat of fusion $\left(\frac{kJ}{kg}, \frac{J}{g}\right)$
- H_{vap} = heat of vaporization $\left(\frac{kJ}{kg}, \frac{J}{g}\right)$
- σ = Stefan-Boltzmann constant $= 5.67 \times 10^{-8}\ \frac{J}{m^2 \cdot s \cdot K^4}$
- V = volume (m^3)
- α = linear coëfficient of thermal expansion* ($°C^{-1}$)
- β = volumetric coëfficient of thermal expansion* ($°C^{-1}$)
- P = power (W)
- P = pressure (Pa)
- n = number of moles (mol)
- N = number of molecules
- R = gas constant $= 8.31\ \frac{J}{mol \cdot K}$
- k_B = Boltzmann constant $= 1.38 \times 10^{-23}\ \frac{J}{K}$
- U = internal energy (J)
- W = work (J, N·m)
- v_{rms} = root mean square speed $\left(\frac{m}{s}\right)$
- μ = molecular mass* (kg)
- M = molar mass* $\left(\frac{kg}{mol}\right)$
- K = kinetic energy (J)
- Q_{rev} = "reversible" heat (J)
- S = entropy $\left(\frac{J}{K}\right)$
- A = Helmholtz free energy (J)

*characteristic property of a substance (to be looked up)

Table I. Thermodynamics Equation Map

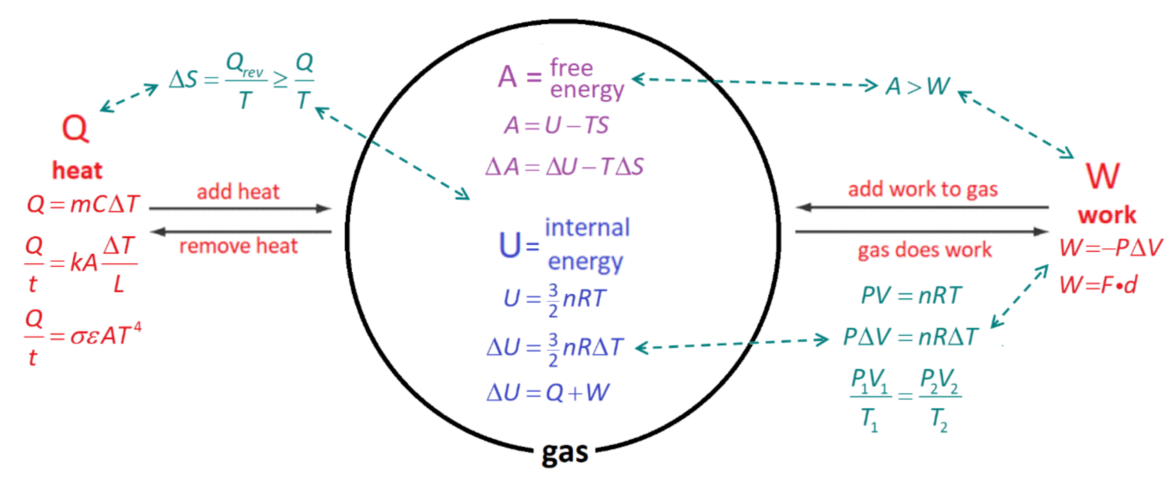


Table J. Pressure-Volume Curves and Equations

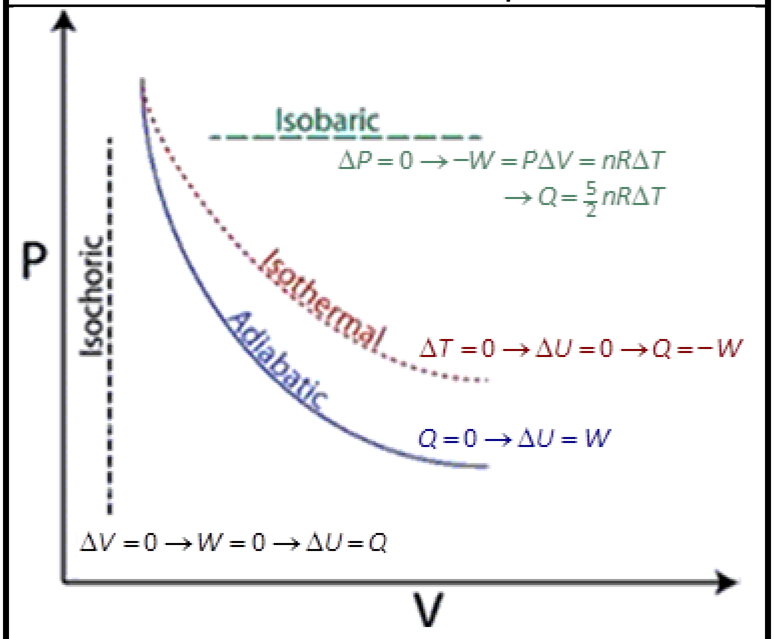


Table K. Thermal Properties of Selected Materials

Substance	Melting Point (°C)	Boiling Point (°C)	Heat of Fusion ΔH_{fus} $\left(\frac{kJ}{kg}, \frac{J}{g}\right)$	Heat of Vaporiz-ation ΔH_{vap} $\left(\frac{kJ}{kg}, \frac{J}{g}\right)$	Specific Heat Capacity C $\left(\frac{kJ}{kg \cdot °C}\right)$ at 25°C	Thermal Conduct-ivity k $\left(\frac{J}{m \cdot s \cdot °C}\right)$ at 25°C	Emissivity ε black body = 1	Coefficients of Expansion at 20°C: Linear α (°C^{-1})	Coefficients of Expansion at 20°C: Volumetric β (°C^{-1})
air (gas)	—	—	—	—	1.012	0.024	—	—	—
aluminum (solid)	659	2467	395	10460	0.897	250	0.09*	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	0.03*	1.7×10^{-5}	5.1×10^{-5}
brass (solid)	—	—	—	—	0.380	120	0.03*	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	0.92	8.5×10^{-6}	2.55×10^{-5}
gold (solid)	1063	2660	64.4	1577	0.129	310	0.025*	1.4×10^{-5}	4.2×10^{-5}
granite (solid)	1240	—	—	—	0.790	1.7–4.0	0.96	—	—
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	0.31	1.18×10^{-5}	3.33×10^{-5}
lead (solid)	327	1750	24.7	870	0.160	35	0.06	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	0.025*	1.8×10^{-5}	5.4×10^{-5}
zinc (solid)	420	906	112	1760	0.387	120	0.05*	$\sim 3\times10^{-5}$	8.9×10^{-5}
steam (gas) @ 100°C			—	2260	2.080	0.016	—	—	—
water (liq.) @ 25°C	0	100	334		4.181	0.58	0.95	6.9×10^{-5}	2.07×10^{-4}
ice (solid) @ −10°C				—	2.11	2.18	0.97	—	—

*polished surface

Table L. Electricity Formulas & Equations

Electrostatic Charges & Electric Fields	$\vec{\boldsymbol{F}}_e = \frac{kq_1q_2}{r^2} = \frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r^2}$ $\vec{\boldsymbol{E}} = \frac{\vec{\boldsymbol{F}}_e}{q} = \frac{Q}{\varepsilon_o A}$ $\quad \vec{\boldsymbol{E}} = \frac{kq}{r^2} = \frac{1}{4\pi\varepsilon_o}\cdot\frac{q}{r^2} = \frac{\Delta V}{\Delta r}$ $W = q\vec{\boldsymbol{E}}\bullet\vec{\boldsymbol{d}} = qEd_{\parallel} = qEd\cos\theta$ $\Delta V = \frac{W}{q} = \vec{\boldsymbol{E}}\bullet\vec{\boldsymbol{d}} = Ed_{\parallel} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r}$ $\Delta U_E = q\Delta V \qquad U_E = \frac{kq_1q_2}{r}$
Circuits and Electrical Components	$\Delta V = IR \qquad I = \frac{\Delta Q}{\Delta t} = \frac{\Delta V}{R}$ $\mathcal{E} = IR$ $P = I\Delta V = I^2R = \frac{(\Delta V)^2}{R}$ $W = Pt = I\Delta Vt$ $R = \frac{\rho L}{A}$ $C = \kappa\varepsilon_o\frac{A}{d}$ $Q = C\Delta V$ $U_{capacitor} = \frac{1}{2}Q\Delta V = \frac{1}{2}C(\Delta V)^2$ $P_{total} = P_1 + P_2 + P_3 + \ldots = \sum P_i$ $U_{total} = U_1 + U_2 + U_3 + \ldots = \sum U_i$
Series Circuits (or Series Sections of Circuits)	$I_{total} = I_1 = I_2 = I_3 = \ldots$ $\Delta V_{total} = \Delta V_1 + \Delta V_2 + \Delta V_3 + \ldots = \sum \Delta V_i$ $R_{equiv.} = R_1 + R_2 + R_3 + \ldots = \sum R_i$ $Q_{total} = Q_1 = Q_2 = Q_3 = \ldots$ $\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots = \sum\frac{1}{C_i}$
Parallel Circuits (or Parallel Sections of Circuits)	$I_{total} = I_1 + I_2 + I_3 + \ldots = \sum I_i$ $\Delta V_{total} = \Delta V_1 = \Delta V_2 = \Delta V_3 = \ldots$ $\frac{1}{R_{equiv.}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots = \sum\frac{1}{R_i}$ $Q_{total} = Q_1 + Q_2 + Q_3 + \ldots = \sum Q_i$ $C_{total} = C_1 + C_2 + C_3 + \ldots = \sum C_i$
Resistor-Capacitor (RC) Circuits	charging: $\frac{I}{I_o} = e^{-t/RC}$ charging: $\frac{Q}{Q_{max}} = 1 - e^{-t/RC}$ discharging: $\frac{I}{I_o} = \frac{V}{V_o} = \frac{Q}{Q_{max}} = e^{-t/RC}$

var. = name of quantity (unit)

Δ = change in something. (*E.g.,* Δx = change in x)
$\vec{\boldsymbol{F}}_e$ = force due to electric field (N)
ε_o = electric permittivity of a vacuum
$= 8.85\times10^{-12}\ \frac{A^2\cdot s^4}{kg\cdot m^3}$
k = electrostatic constant
$= \frac{1}{4\pi\varepsilon_o} = 9.0\times10^{9}\ \frac{N\cdot m^2}{C^2}$
q = point charge (C)
Q = charge (C)
$\vec{\boldsymbol{E}}$ = electric field $\left(\frac{N}{C}, \frac{V}{m}\right)$
V = electric potential (V)
ΔV = voltage = electric potential difference (V)
$\mathcal{E}$ = emf = electromotive force (V)
W = work (J, N·m)
$\kappa = \varepsilon_r$ = relative permittivity* (*dimensionless*)
d = distance (m)
r = radius (m)
$\vec{\boldsymbol{I}}$ = current (A)
t = time (s)
R = resistance (Ω)
P = power (W)
ρ = resistivity (Ω·m)
L = length (m)
A = cross-sectional area (m^2)
C = capacitance (F)
U = potential energy (J)
π = pi (mathematical constant)
= 3.14159 26535 89793...
e = Euler's number (mathematical constant)
= 2.78182 81812 84590...

___

*characteristic property of a substance (to be looked up)

Table M. Electricity & Magnetism Formulas & Equations

Magnetism and Electro-magnetism	$\vec{F}_M = q(\vec{v} \times \vec{B})$ $F_M = qvB\sin\theta$ $\vec{F}_M = \ell(\vec{I} \times \vec{B})$ $F_M = \ell I B\sin\theta$ $\Delta V = \ell(\vec{v} \times \vec{B})$ $\Delta V = \ell vB\sin\theta$ $B = \frac{\mu_o}{2\pi}\frac{I}{r}$ $\Phi_B = \vec{B} \bullet \vec{A} = BA\cos\theta$ $\mathcal{E} = \frac{\Delta\Phi_B}{\Delta t} = BLv$
Electro-magnetic Induction	$\frac{\#turns_{in}}{\#turns_{out}} = \frac{V_{in}}{V_{out}} = \frac{I_{out}}{I_{in}}$ $P_{in} = P_{out}$

var. = name of quantity (unit)

- Δ = change in something. (*E.g.,* Δx = change in x)
- $\vec{F}_e$ = force due to electric field (N)
- $\vec{v}$ = velocity (of moving charge or wire) $\left(\frac{m}{s}\right)$
- q = point charge (C)
- ΔV = voltage = electric potential difference (V)
- $\mathcal{E}$ = emf = electromotive force (V)
- r = radius (m) = distance from wire
- $\vec{I}$ = current (A)
- L = length (m)
- t = time (s)
- A = cross-sectional area (m^2)
- $\vec{B}$ = magnetic field (T)
- μ_o = magnetic permeability of a vacuum = $4\pi \times 10^{-7}\ \frac{T \cdot m}{A}$
- Φ_B = magnetic flux ($T \cdot m^2$)

Table N. 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 O. Symbols Used in Electrical Circuit Diagrams

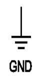
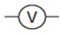
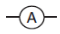
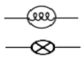
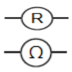
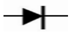
Component	Symbol	Component	Symbol
wire		battery	
switch		ground	
fuse		resistor	
voltmeter		variable resistor (rheostat, potentiometer, dimmer)	
ammeter		lamp (light bulb)	
ohmmeter		capacitor	
		diode	

Table P. Resistivities at 20°C

Conductors		Semiconductors		Insulators	
Substance	**Resistivity** $(\Omega \cdot m)$	**Substance**	**Resistivity** $(\Omega \cdot m)$	**Substance**	**Resistivity** $(\Omega \cdot m)$
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 Q. Waves & Optics Formulas & Equations

Waves	$v = \lambda f$ $f = \dfrac{1}{T}$ $v_{\text{wave on a string}} = \sqrt{\dfrac{F_T}{\mu}}$ $f_{\text{doppler shifted}} = f\left(\dfrac{\vec{\boldsymbol{v}}_{\text{wave}} + \vec{\boldsymbol{v}}_{\text{detector}}}{\vec{\boldsymbol{v}}_{\text{wave}} + \vec{\boldsymbol{v}}_{\text{source}}}\right)$ $x = A\cos(2\pi ft + \phi)$
Reflection, Refraction & Diffraction	$\theta_i = \theta_r$ $n = \dfrac{c}{v}$ $n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\theta_c = \sin^{-1}\left(\dfrac{n_2}{n_1}\right)$ $\dfrac{n_2}{n_1} = \dfrac{v_1}{v_2} = \dfrac{\lambda_1}{\lambda_2}$ $\Delta L = m\lambda = d\sin\theta$
Mirrors & Lenses	$f = \dfrac{r_c}{2}$ $\dfrac{1}{s_i} + \dfrac{1}{s_o} = \dfrac{1}{f}$ $M = \dfrac{h_i}{h_o} = -\dfrac{s_i}{s_o}$

var. = name of quantity (unit)

- Δ = change in something (*E.g.,* Δx = change in x)
- v = velocity of wave $\left(\frac{\text{m}}{\text{s}}\right)$
- $\vec{\boldsymbol{v}}$ = velocity of source or detector $\left(\frac{\text{m}}{\text{s}}\right)$
- f = frequency (Hz)
- λ = wavelength (m)
- A = amplitude (m)
- x = position (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 = angle (°, rad)
- ϕ = phase offset (°, rad)
- 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 $= 3.00\times10^8\ \frac{\text{m}}{\text{s}}$
- $f = s_f = d_f$ = distance to focus of mirror/lens (m)
- r_c = radius of curvature of spherical mirror (m)
- $s_i = d_i$ = distance from mirror/lens to image (m)
- $s_o = d_o$ = distance from mirror/lens to object (m)
- h_i = height of image (m)
- h_o = height of object (m)
- M = magnification (*dimensionless*)
- d = separation (m)
- L = distance from the opening (m)
- m = an integer

*characteristic property of a substance (to be looked up)

Table R. Absolute Indices of Refraction

Measured using $f = 5.89\times10^{14}$ Hz (yellow light) at 20 °C unless otherwise specified

Substance	Index of Refraction	Substance	Index of Refraction
air (0 °C and 1 atm)	1.000293	silica (quartz), fused	1.459
ice (0 °C)	1.309	Plexiglas	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

Figure S. The Electromagnetic Spectrum

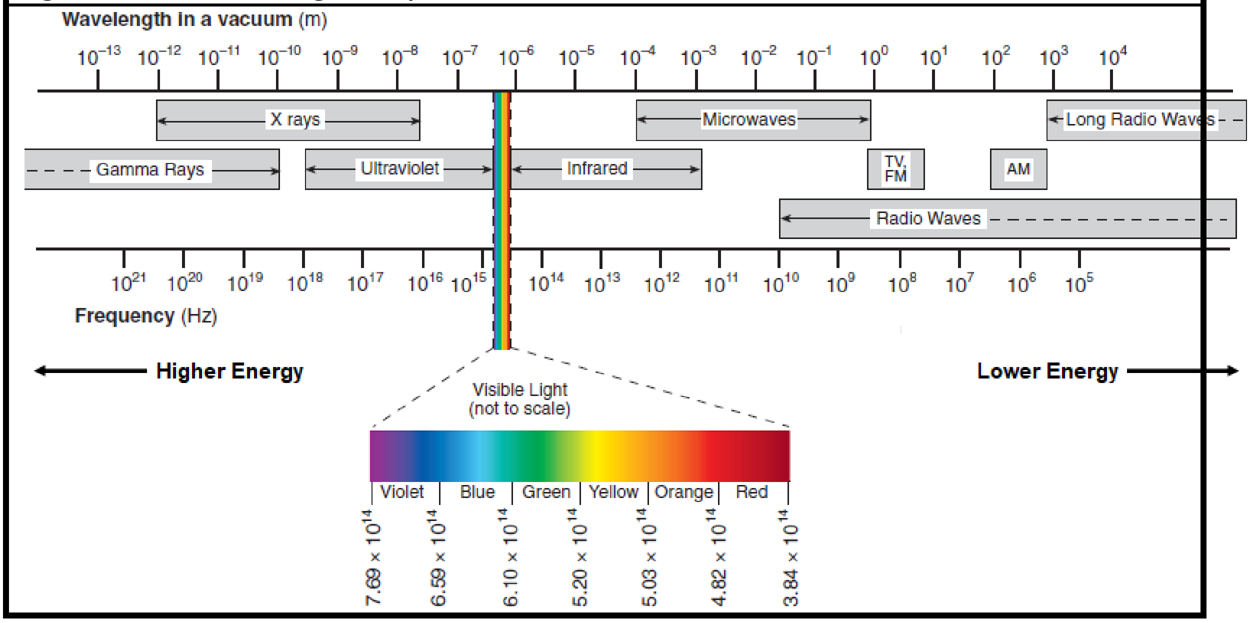


Table T. Planetary Data

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Distance from Sun (m)	5.79×10^{10}	1.08×10^{11}	1.50×10^{11}	2.28×10^{11}	7.79×10^{11}	1.43×10^{12}	2.87×10^{12}	4.52×10^{12}	5.91×10^{12}
Radius (m)	2.44×10^{6}	6.05×10^{6}	6.38×10^{6}	3.40×10^{6}	7.15×10^{7}	6.03×10^{7}	2.56×10^{7}	2.48×10^{7}	1.19×10^{6}
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}	1.30×10^{22}
Density $\left(\frac{kg}{m^3}\right)$	5429	5243	5514	3934	1326	687	1270	1638	1850
Orbit (years)	0.24	0.61	1.00	1.88	11.8	29	84	164	248
Rotation Period (hours)	1408	−5833	23.9	24.6	9.9	10.7	−17.2	16.1	−153.3
Tilt of axis	0.034°	177.4°	23.4°	25.2°	3.1°	26.7°	97.8°	28.3°	122.5°
# of observed satellites	0	0	1	2	92	83	27	14	5
Mean temp. (°C)	167	464	15	−65	−110	−140	−195	−200	−225
Global magnetic field	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes

Data from NASA Planetary Fact Sheet, https://nssdc.gsfc.nasa.gov/planetary/factsheet/ last updated 11 February 2023.

Table U. 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 V. Fluids Formulas and Equations		
Fluids	$\rho = \frac{m}{V}$ $P = \frac{F}{A}$ $\frac{F_1}{A_1} = \frac{F_2}{A_2}$ $P_{\text{hydrostatic}} = P_H = \rho g h$ $F_B = \rho V_d g$ $P_{\text{dynamic}} = P_D = \frac{1}{2}\rho v^2$ $A_1 v_1 = A_2 v_2$ $P_{total} = P_{ext.} + P_H + P_D$ $P_1 + P_{H,1} + P_{D,1} = P_2 + P_{H,2} + P_{D,2}$ $P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$	*var.* = name of quantity (unit) Δ = change in something. (*E.g.,* Δx = change in *x*) ρ = density $\left(\frac{\text{kg}}{\text{m}^3}\right)$ m = mass (kg) V = volume (m^3) P = presure (Pa) g = gravitational field = $9.8\,\frac{\text{N}}{\text{kg}} \approx 10\,\frac{\text{N}}{\text{kg}}$ h = height or depth (m) A = area (m^2) v = velocity (of fluid) $\left(\frac{\text{m}}{\text{s}}\right)$ F = force (N) _______________ *characteristic property of a substance (to be looked up)

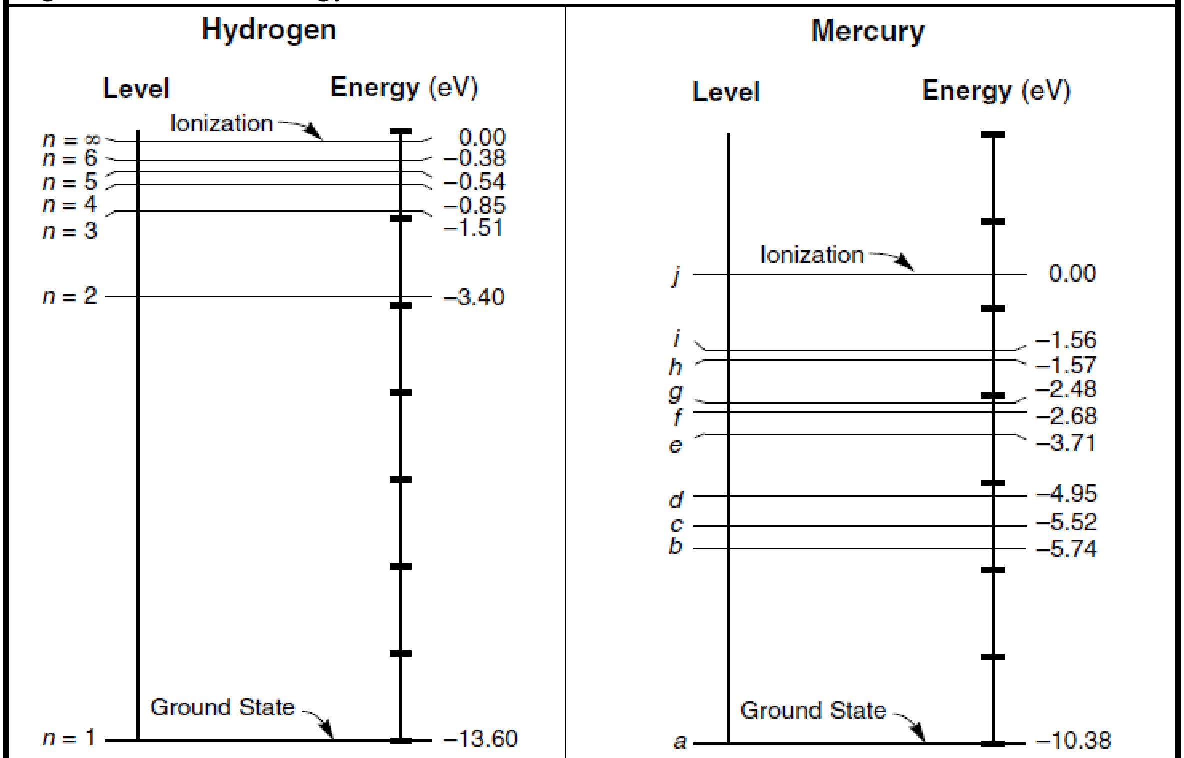
Table W. Properties of Water and Air

Temp. (°C)	Water			Air	
	Density $\left(\frac{\text{kg}}{\text{m}^3}\right)$	**Speed of Sound** $\left(\frac{\text{m}}{\text{s}}\right)$	**Vapor Pressure (Pa)**	**Density** $\left(\frac{\text{kg}}{\text{m}^3}\right)$	**Speed of Sound** $\left(\frac{\text{m}}{\text{s}}\right)$
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 X. Atomic & Particle Physics (Modern Physics)

Energy	$E_{photon} = hf = \frac{hc}{\lambda} = pc = \hbar\omega$ $E_{k,\max} = hf - \phi$ $\lambda = \frac{h}{p}$ $E_{photon} = E_i - E_f$ $E^2 = (pc)^2 + (mc^2)^2$ $\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$	*var.* = name of quantity (unit) Δ = change in something. (*E.g.*, Δx = change in x) E = energy (J) h = Planck's constant = 6.63×10^{-34} J·s $\hbar$ = reduced Planck's constant = $\frac{h}{2\pi} = 1.05\times10^{-34}$ J·s f = frequency (Hz) v = velocity $\left(\frac{m}{s}\right)$ c = speed of light = $3.00\times10^{8}\ \frac{m}{s}$ λ = wavelength (m) p = momentum (N·s) m = mass (kg) K = kinetic energy (J) ϕ = work function* (J) R_H = Rydberg constant = $1.10\times10^{7}\ m^{-1}$
Special Relativity	$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$ $\gamma = \frac{L_o}{L} = \frac{\Delta t'}{\Delta t} = \frac{m_{rel}}{m_o}$	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) *characteristic property of a substance (to be looked up)

Figure Y. Quantum Energy Levels



Energy Levels for the Hydrogen Atom

A Few Energy Levels for the Mercury Atom

Figure Z. Particle Sizes

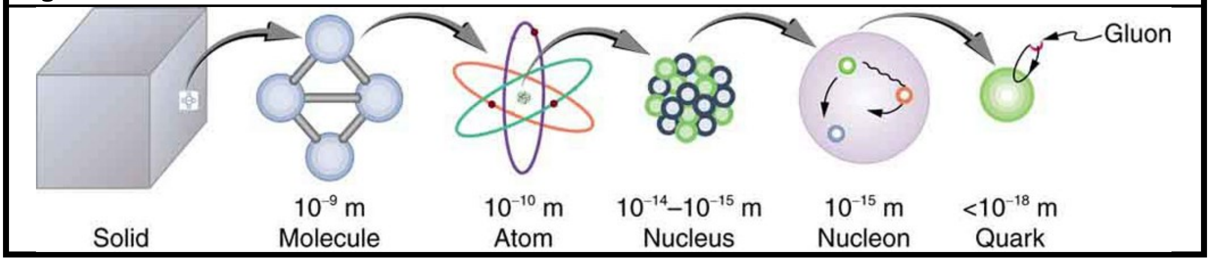


Figure AA. Classification of Matter

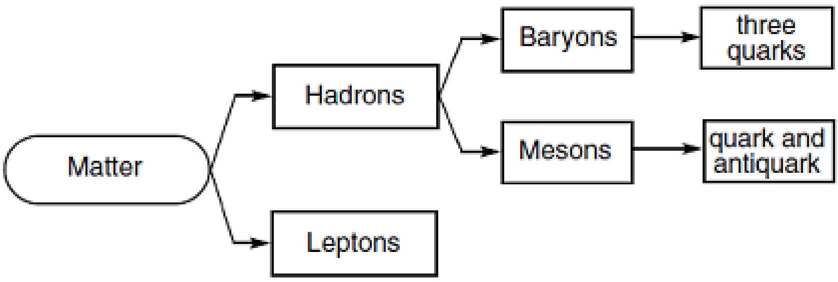


Table BB. The Standard Model of Elementary Particles

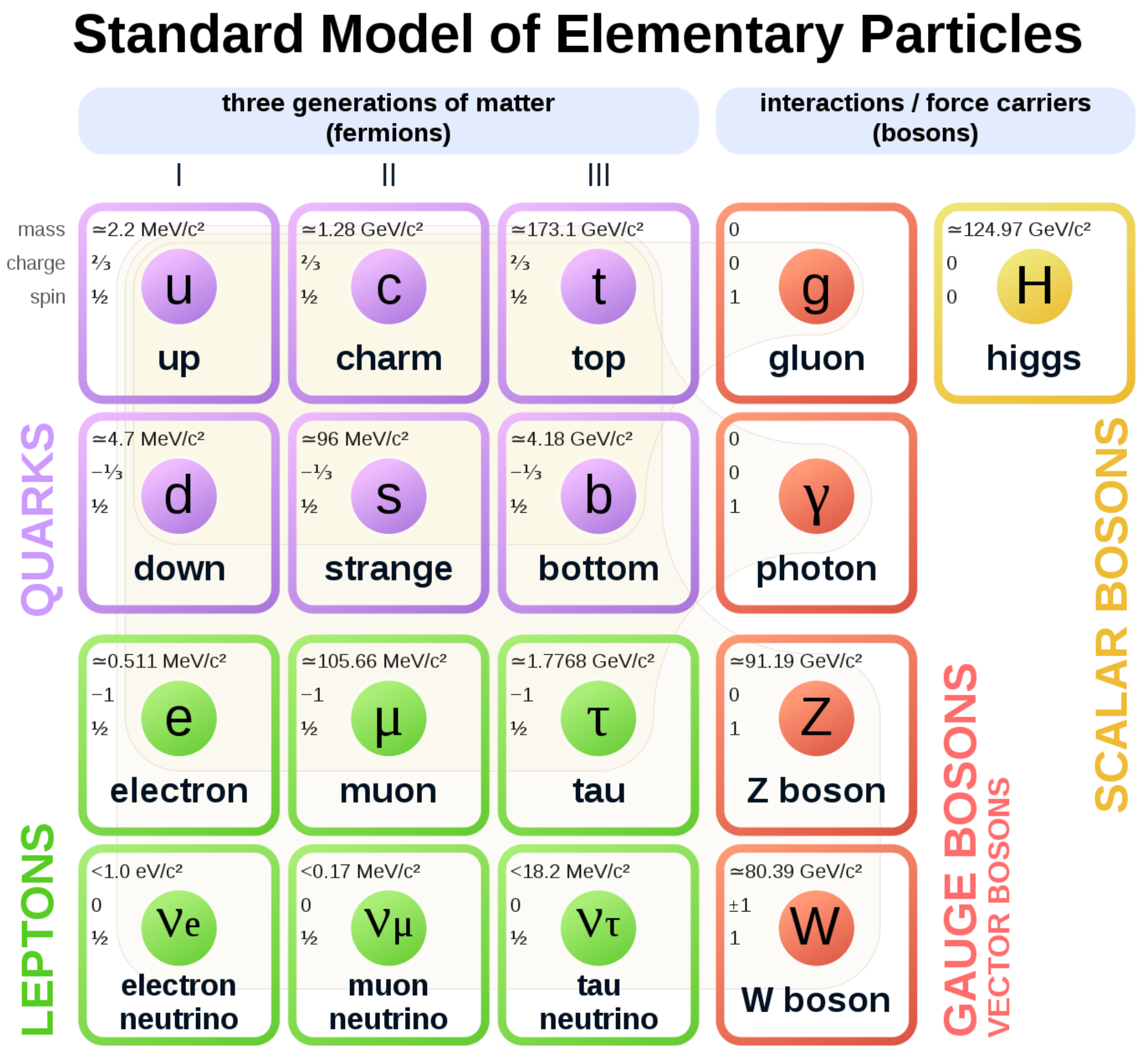


Figure CC. Periodic Table of the Elements

Period	1 I A	2 II A	3 III B	4 IV B	5 V B	6 VI B	7 VII B	8 VIII B	9 VIII B	10 VIII B	11 I B	12 II B	13 III A	14 IV A	15 V A	16 VI A	17 VII A	18 VIII A
1	1 **H** hydrogen 1.008																	2 **He** helium 4.003
2	3 **Li** lithium 6.968	4 **Be** beryllium 9.012											5 **B** boron 10.81	6 **C** carbon 12.01	7 **N** nitrogen 14.01	8 **O** oxygen 16.00	9 **F** fluorine 19.00	10 **Ne** neon 20.18
3	11 **Na** sodium 22.99	12 **Mg** magnesium 24.31											13 **Al** aluminum 26.98	14 **Si** silicon 28.09	15 **P** phosphorus 30.97	16 **S** sulfur 32.07	17 **Cl** chlorine 35.45	18 **Ar** argon 39.95
4	19 **K** potassium 39.10	20 **Ca** calcium 40.08	21 **Sc** scandium 44.96	22 **Ti** titanium 47.87	23 **V** vanadium 50.94	24 **Cr** chromium 52.00	25 **Mn** manganese 54.94	26 **Fe** iron 55.85	27 **Co** cobalt 58.93	28 **Ni** nickel 58.69	29 **Cu** copper 63.55	30 **Zn** zinc 65.38	31 **Ga** gallium 69.72	32 **Ge** germanium 72.63	33 **As** arsenic 74.92	34 **Se** selenium 78.97	35 **Br** bromine 79.90	36 **Kr** krypton 83.80
5	37 **Rb** rubidium 85.47	38 **Sr** strontium 87.62	39 **Y** yttrium 88.91	40 **Zr** zirconium 91.22	41 **Nb** niobium 92.91	42 **Mo** molybdenum 95.95	43 **Tc** technetium 98	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9	46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 **Xe** xenon 131.3
6	55 **Cs** cesium 132.9	56 **Ba** barium 137.3	71 **Lu** lutetium 175.0	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.8	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2	78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 **Hg** mercury 200.6	81 **Tl** thallium 204.4	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium 209	85 **At** astatine 210	86 **Rn** radon 222
7	87 **Fr** francium 223	88 **Ra** radium 226	103 **Lr** lawrencium 262	104 **Rf** rutherfordium 267	105 **Db** dubnium 268	106 **Sg** seaborgium 271	107 **Bh** bohrium 272	108 **Hs** hassium 270	109 **Mt** meitnerium 276	110 **Ds** darmstadtium 281	111 **Rg** roentgentium 280	112 **Cn** copernicum 285	113 **Nh** nihonium 284	114 **Fl** flerovium 289	115 **Mc** moscovium 288	116 **Lv** livermorium 293	117 **Ts** tennessine 292	118 **Og** oganesson 294

lanthanides (rare earth metals)	57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium 145	62 **Sm** samarium 150.4	63 **Eu** europium 152.0	64 **Gd** gadolinium 157.3	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.1
actinides	89 **Ac** actinium 227	90 **Th** thorium 232.0	91 **Pa** protactinium 231.0	92 **U** uranium 238.0	93 **Np** neptunium 237	94 **Pu** plutonium 244	95 **Am** americium 243	96 **Cm** curium 247	97 **Bk** berkelium 247	98 **Cf** californium 251	99 **Es** einsteinium 252	100 **Fm** fermium 257	101 **Md** mendelevium 258	102 **No** nobelium 259

Table DD. Symbols Used in Nuclear Physics		
Name	**Notation**	**Symbol**
alpha particle	${}^{4}_{2}He$ or ${}^{4}_{2}\alpha$	□
beta particle (electron)	${}^{0}_{-1}e$ or ${}^{0}_{-1}\beta$	□−
gamma radiation	${}^{0}_{0}\gamma$	□
neutron	${}^{1}_{0}n$	*n*
proton	${}^{1}_{1}H$ or ${}^{1}_{1}p$	*p*
positron	${}^{0}_{+1}e$ or ${}^{0}_{+1}\beta$	□+

Table FF. Constants Used in Nuclear Physics	
Constant	**Value**
mass of an electron (m_e)	0.00055 amu
mass of a proton (m_p)	1.00728 amu
mass of a neutron (m_n)	1.00867 amu
Bequerel (Bq)	1 disintegration/second
Curie (Ci)	3.7 x 10^{10} Bq

Figure GG. Neutron/Proton Stability Band

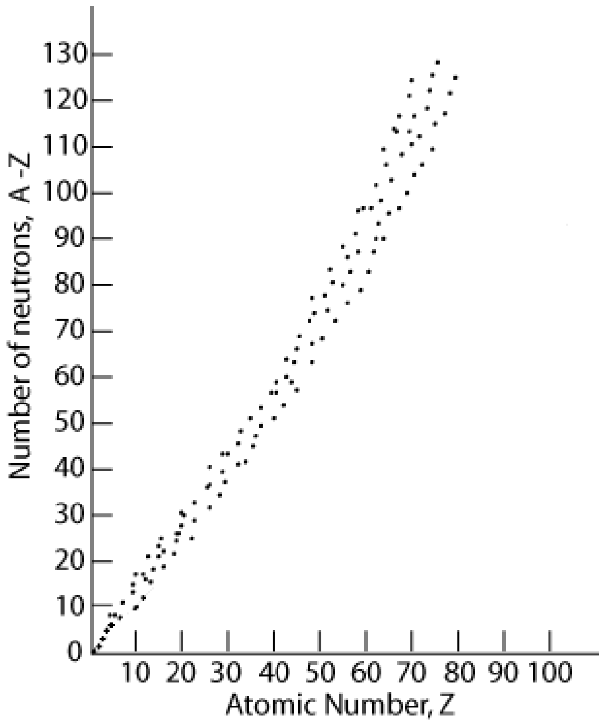


Table EE. Selected Radioisotopes		
Nuclide	**Half-Life**	**Decay Mode**
${}^{3}H$	12.26 y	□−
${}^{14}C$	5730 y	□−
${}^{16}N$	7.2 s	□−
${}^{19}Ne$	17.2 s	□+
${}^{24}Na$	15 h	□−
${}^{27}Mg$	9.5 min	□−
${}^{32}P$	14.3 d	□−
${}^{36}Cl$	3.01 × 10^{5} y	□−
${}^{37}K$	1.23 s	□+
${}^{40}K$	1.26 × 10^{9} y	□+
${}^{42}K$	12.4 h	□−
${}^{37}Ca$	0.175 s	□−
${}^{51}Cr$	27.7 d	□
${}^{53}Fe$	8.51 min	□−
${}^{59}Fe$	46.3 d	□−
${}^{60}Co$	5.26 y	□−
${}^{85}Kr$	10.76 y	□−
${}^{87}Rb$	4.8 × 10^{10} y	□−
${}^{90}Sr$	28.1 y	□−
${}^{99}Tc$	2.13 x 10^{5} y	□−
${}^{131}I$	8.07 d	□−
${}^{137}Cs$	30.23 y	□−
${}^{153}Sm$	1.93 d	□−
${}^{198}Au$	2.69 d	□−
${}^{222}Rn$	3.82 d	□
${}^{220}Fr$	27.5 s	□
${}^{226}Ra$	1600 y	□
${}^{232}Th$	1.4 x 10^{10} y	□
${}^{233}U$	1.62 x 10^{5} y	□
${}^{235}U$	7.1 x 10^{8} y	□
${}^{238}U$	4.51 x 10^{9} y	□
${}^{239}Pu$	2.44 x 10^{4} y	□
${}^{241}Am$	432 y	□

Table HH. Mathematics Formulas

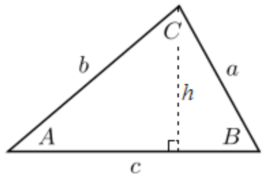
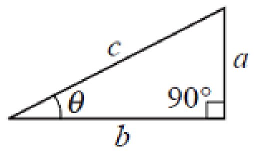
Scientific Notation	$3\times10^4 = 3\times10\,000 = 30\,000 \qquad 2\times10^{-3} = 2\times0.001 = 0.002$ $(3\times10^4)(2\times10^{-3}) = (3\cdot2)(10^4\cdot10^{-3}) = 6\times10^{4+(-3)} = 6\times10^1 = 60$	
Rounding (to underlined place)	$15\,\underline{3}54 \rightarrow 15\,\underline{4}00 \qquad 27\,\underline{2}49.99 \rightarrow 27\,\underline{2}00$ $0.037\,\underline{5}00 \rightarrow 0.037\underline{5}$	
Algebra with Fractions	$\frac{a}{b}+\frac{c}{d} = \frac{a}{b}\cdot\frac{d}{d}+\frac{c}{d}\cdot\frac{b}{b} = \frac{ad+cb}{bd}$ $\frac{a}{b}\cdot\frac{c}{d}=\frac{ac}{bd} \qquad \frac{a}{b/c}=a\cdot\frac{c}{b}$ $\frac{a}{x}=b \rightarrow \cancel{x}\cdot\frac{a}{\cancel{x}}=b\cdot x \rightarrow a=bx \rightarrow \frac{a}{b}=\frac{bx}{\cancel{b}} \rightarrow \frac{a}{b}=x$	
Quadratic Equation	$ax^2+bx+c=0 \quad\rightarrow\quad x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$	
All Triangles	$A=\frac{1}{2}bh$ $\frac{a}{\sin A}=\frac{b}{\sin B}=\frac{c}{\sin C}$ $c^2=a^2+b^2-2ab\cos C$	
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	$A=\bar{b}h$	$a,b,c=$ length of a side of a triangle $\theta=$ angle $A=$ area $C=$ circumference $S=$ surface area $V=$ volume $b=$ base $\bar{b}=$ average base $=\frac{b_1+b_2}{2}$ $h=$ height $L=$ length $w=$ width $r=$ radius
Rectangular Solids	$V=Lwh$	
Circles	$C=2\pi r$ $A=\pi r^2$	
Cylinders	$S=2\pi rL+2\pi r^2=2\pi r(L+r)$ $V=\pi r^2L$	
Spheres	$S=4\pi r^2$ $V=\frac{4}{3}\pi r^3$	

Table II. 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 JJ. 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 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	≈	$^{1}/_{16}$ teaspoon (tsp.)		
	1 dash	≈	$^{1}/_{8}$ 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. (U.S.)	≡	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 / Velocity	1 $^{m}/_{s}$	=	3.6 $^{km}/_{h}$	≈	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	≈	1.06 kJ		
Power	1 hp	≈	746 W		
	1 kW	≈	1.34 hp		
Temper-ature	0 K	≡	−273.15 °C	=	absolute zero
	0 °R	≡	−459.67 °F	=	absolute zero
	0 °F	≈	−18 °C ≡ 459.67 °R		
	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 KK. Greek Alphabet

Α	α	alpha
Β	β	beta
Γ	γ	gamma
Δ	δ	delta
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	phi
Χ	χ	chi
Ψ	ψ	psi
Ω	ω	omega

Table LL. Decimal Equivalents

$\frac{1}{2}=0.5$	$\frac{1}{5}=0.2$
$\frac{1}{3}=0.33\overline{3}$	$\frac{2}{5}=0.4$
$\frac{2}{3}=0.66\overline{6}$	$\frac{3}{5}=0.6$
$\frac{1}{4}=0.25$	$\frac{4}{5}=0.8$
$\frac{3}{4}=0.75$	$\frac{1}{8}=0.125$
$\frac{1}{6}=0.166\overline{6}$	$\frac{3}{8}=0.375$
$\frac{5}{6}=0.833\overline{3}$	$\frac{5}{8}=0.625$
$\frac{1}{7}=0.\overline{142857}$	$\frac{7}{8}=0.875$
$\frac{2}{7}=0.\overline{285714}$	$\frac{1}{9}=0.11\overline{1}$
$\frac{3}{7}=0.\overline{428571}$	$\frac{2}{9}=0.22\overline{2}$
$\frac{4}{7}=0.\overline{571428}$	$\frac{4}{9}=0.44\overline{4}$
$\frac{5}{7}=0.\overline{714285}$	$\frac{5}{9}=0.55\overline{5}$
$\frac{6}{7}=0.\overline{857142}$	$\frac{7}{9}=0.77\overline{7}$
$\frac{1}{11}=0.09\overline{09}$	$\frac{8}{9}=0.88\overline{8}$
$\frac{2}{11}=0.18\overline{18}$	$\frac{1}{16}=0.0625$
$\frac{3}{11}=0.27\overline{27}$	$\frac{3}{16}=0.1875$
$\frac{4}{11}=0.36\overline{36}$	$\frac{5}{16}=0.3125$
$\frac{5}{11}=0.45\overline{45}$	$\frac{7}{16}=0.4375$
$\frac{6}{11}=0.54\overline{54}$	$\frac{9}{16}=0.5625$
$\frac{7}{11}=0.63\overline{63}$	$\frac{11}{16}=0.6875$
$\frac{8}{11}=0.72\overline{72}$	$\frac{13}{16}=0.8125$
$\frac{9}{11}=0.81\overline{81}$	$\frac{15}{16}=0.9375$
$\frac{10}{11}=0.90\overline{90}$	