

Appendix: Physics Reference Tables

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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

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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 $9.80665 \frac{m}{s^2}$	$9.8 \frac{m}{s^2} \equiv 9.8 \frac{N}{kg}$ or $10 \frac{m}{s^2} \equiv 10 \frac{N}{kg}$
universal gravitational constant	G	$6.67384(80) \times 10^{-11} \frac{Nm^2}{kg^2}$	$6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$
speed of light in a vacuum	c	$299\,792\,458 \frac{m}{s}^*$	$3.00 \times 10^8 \frac{m}{s}$
elementary charge (proton or electron)	e	$\pm 1.602176634 \times 10^{-19} C^*$	$\pm 1.60 \times 10^{-19} C$
1 coulomb (C)		$6.241\,509\,074 \times 10^{18}$ elementary charges	6.24×10^{18} elementary charges
(electric) permittivity of a vacuum	ϵ_0	$8.854\,187\,82 \times 10^{-12} \frac{A^2 \cdot s^4}{kg \cdot m^3}$	$8.85 \times 10^{-12} \frac{A^2 \cdot s^4}{kg \cdot m^3}$
(magnetic) permeability of a vacuum	μ_0	$4\pi \times 10^{-7} = 1.256\,637\,06 \times 10^{-6} \frac{Tm}{A}$	$1.26 \times 10^{-6} \frac{Tm}{A}$
electrostatic constant	k	$\frac{1}{4\pi\epsilon_0} = 8.987\,551\,787\,368\,176\,4 \times 10^9 \frac{Nm^2}{C^2}^*$	$8.99 \times 10^9 \frac{Nm^2}{C^2}$
1 electron volt (eV)		$1.602\,176\,565(35) \times 10^{-19} J$	$1.60 \times 10^{-19} J$
Planck's constant	h	$6.626\,070\,15 \times 10^{-34} J \cdot s^*$	$6.63 \times 10^{-34} J \cdot s$
1 universal (atomic) mass unit (u)		$931.494\,061(21) MeV/c^2$ $1.660\,538\,921(73) \times 10^{-27} kg$	$931 MeV/c^2$ $1.66 \times 10^{-27} kg$
Avogadro's constant	N_A	$6.022\,140\,76 \times 10^{23} mol^{-1}^*$	$6.02 \times 10^{23} mol^{-1}$
Boltzmann constant	k_B	$1.380\,649 \times 10^{-23} \frac{J}{K}^*$	$1.38 \times 10^{-23} \frac{J}{K}$
universal gas constant	R	$8.314\,4621(75) \frac{J}{molK}$	$8.31 \frac{J}{molK}$
Rydberg constant	R_H	$\frac{m_e e^4}{8\epsilon_0^2 h^3 c} = 10\,973\,731.6 \frac{1}{m}$	$1.10 \times 10^7 m^{-1}$
Stefan-Boltzmann constant	σ	$\frac{2\pi^5 R^4}{15h^3 c^2} = 5.670\,374\,419 \times 10^{-8} \frac{J}{m^2 \cdot s \cdot K^4}$	$5.67 \times 10^{-8} \frac{J}{m^2 \cdot s \cdot K^4}$
standard atmospheric pressure at sea level		$101\,325 Pa \equiv 1.01325 bar^*$	$100\,000 Pa \equiv 1.0 bar$
rest mass of an electron	m_e	$9.109\,382\,15(45) \times 10^{-31} kg$	$9.11 \times 10^{-31} kg$
mass of a proton	m_p	$1.672\,621\,777(74) \times 10^{-27} kg$	$1.67 \times 10^{-27} kg$
mass of a neutron	m_n	$1.674\,927\,351(74) \times 10^{-27} kg$	$1.67 \times 10^{-27} kg$

*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{x}	meter*	m	m
distance/displacement, (length, height)	$d, \vec{d}, (L, h)$	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{v}	meter/second	$\frac{m}{s}$	$\frac{m}{s}$
speed of light	c			
angular velocity	$\vec{\omega}$	radians/second	$\frac{1}{s^2}, s^{-1}$	$\frac{1}{s^2}, s^{-1}$
acceleration	\vec{a}	meter/second ²	$\frac{m}{s^2}$	$\frac{m}{s^2}$
acceleration due to gravity	\vec{g}			
angular acceleration	$\vec{\alpha}$	radians/second ²	$\frac{1}{s^2}, s^{-2}$	$\frac{1}{s^2}, s^{-2}$
mass	m	kilogram*	kg	kg
force	\vec{F}	newton	N	$\frac{kg \cdot m}{s^2}$
gravitational field	\vec{g}	newton/kilogram	$\frac{N}{kg}$	$\frac{m}{s^2}$
pressure	P	pascal	Pa	$\frac{kg}{ms^2}$
energy (generic)	E			
potential energy	U			
kinetic energy	K, E_k	joule	J	$\frac{kg \cdot m^2}{s^2}$
heat	Q			
work	W	joule, newton-meter	J, N·m	$\frac{kg \cdot m^2}{s^2}$
torque	$\vec{\tau}$	newton-meter	N·m	$\frac{kg \cdot m^2}{s^2}$
power	P	watt	W	$\frac{kg \cdot m^2}{s^3}$
momentum	\vec{p}	newton-second	N·s	$\frac{kg \cdot m}{s}$
impulse	\vec{j}			
moment of inertia	I	kilogram-meter ²	kg·m ²	kg·m ²
angular momentum	\vec{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{I}	ampere*	A	A
electric charge	q	coulomb	C	A·s
electric potential	V			
potential difference (voltage)	ΔV	volt	V	$\frac{kg \cdot m^2}{A \cdot s^3}$
electromotive force (emf)	\mathcal{E}			
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{E}	newton/coulomb volt/meter	$\frac{N}{C}, \frac{V}{m}$	$\frac{kg \cdot m}{A \cdot s^3}$
magnetic field	\vec{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)	$\vec{d} = \Delta\vec{x} = \vec{x} - \vec{x}_o$ $\frac{\vec{d}}{t} = \frac{\vec{v}_o + \vec{v}}{2} (= \vec{v}_{ave.})$ $\vec{v} - \vec{v}_o = \vec{a}t$ $\vec{d} = \vec{v}_o t + \frac{1}{2}\vec{a}t^2$ $\vec{v}^2 - \vec{v}_o^2 = 2\vec{a}\vec{d}$	<i>var.</i> = 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 ($\frac{m}{s}$) $\vec{v}_{ave.}$ = average velocity ($\frac{m}{s}$) \vec{a} = acceleration ($\frac{m}{s^2}$) f = frequency ($Hz = \frac{1}{s}$) \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 = acceleration due to gravity = $10 \frac{N}{kg} = 10 \frac{m}{s^2}$ on Earth G = gravitational constant = $6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$ r = radius (m)
	Forces & Dynamics	
Circular/ Centripetal Motion & Force	$a_c = \frac{v^2}{r}$ $F_c = ma_c$	μ = coefficient of friction* (<i>dimensionless</i>) θ = angle ($^\circ$, radians) k = spring constant ($\frac{N}{m}$) \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...
Simple Harmonic Motion	$T = \frac{1}{f}$ $T_s = 2\pi\sqrt{\frac{m}{k}} \quad T_p = 2\pi\sqrt{\frac{L}{g}}$ $\vec{F}_s = -k\vec{x}$ $U_s = \frac{1}{2}kx^2$	
Energy, Work & Power	$U_g = mgh = \frac{Gm_1 m_2}{r}$ $K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ $W = \Delta E = \Delta(U_g + K)$ $W = F_{\parallel}d = \vec{F}_{net} \bullet \vec{d} = Fd \cos \theta$ $TME = U_g + K$ $TME_i + W = TME_f$ $P = \frac{W}{t} = \vec{F} \bullet \vec{v} = Fv \cos \theta$	\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 = acceleration due to gravity = $10 \frac{N}{kg} = 10 \frac{m}{s^2}$ on Earth G = gravitational constant = $6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$ r = radius (m)
Momentum	$\vec{p} = \sum m\vec{v}$ $\sum m_i \vec{v}_i + \vec{J} = \sum m_f \vec{v}_f$ $\vec{J} = \Delta\vec{p} = \vec{F}_{net} t$	

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

Table E. Approximate Coefficients 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)	$\Delta\vec{\theta} = \vec{\theta} - \vec{\theta}_0$ $\frac{\Delta\vec{\theta}}{t} = \frac{\vec{\omega}_0 + \vec{\omega}}{2} (= \vec{\omega}_{ave.})$ $\vec{\omega} - \vec{\omega}_0 = \vec{\alpha}t$ $\Delta\vec{\theta} = \vec{\omega}_0 t + \frac{1}{2}\vec{\alpha}t^2$ $\vec{\omega}^2 - \vec{\omega}_0^2 = 2\vec{\alpha}(\Delta\vec{\theta})$	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 ($\frac{m}{s^2}$)
Circular/Centripetal Motion	$s = r\Delta\theta \quad v_T = r\omega \quad a_T = r\alpha$ $a_c = \frac{v^2}{r} = \omega^2 r$	F_c = centripetal force (N) m = mass (kg) r = radius (m) \vec{r} = radius (vector) θ = angle ($^\circ$, radians) $\vec{\omega}$ = angular velocity ($\frac{rad}{s}$) $\vec{\alpha}$ = angular velocity ($\frac{rad}{s^2}$)
Rotational Dynamics	$x_{cm} = \frac{\sum m_i x_i}{\sum m_i}$ $I = \int_0^m r^2 dm$ $F_c = ma_c = m\omega^2 r$ $\vec{\tau} = \vec{r} \times \vec{F} \quad \tau = rF \sin\theta = r_{\perp} F$ $\sum \vec{\tau} = \vec{\tau}_{net} = I\vec{\alpha}$	\vec{r} = torque (N·m) x = position (m) f = frequency (Hz) A = amplitude (m) ϕ = phase offset ($^\circ$, rad) E = energy (J)
Simple Harmonic Motion	$T = \frac{1}{f} = \frac{2\pi}{\omega}$ $x = A \cos(2\pi ft) + \phi$	$K = E_k$ = kinetic energy (J) K_t = translational kinetic energy (J) K_r = rotational kinetic energy (J)
Angular Momentum	$\vec{L} = \vec{r} \times \vec{p} = I\vec{\omega} \quad L = rp \sin\theta = I\omega$ $\Delta\vec{L} = \vec{\tau}\Delta t$	P = power (W) W = work (J, N·m) \vec{p} = momentum (N·s) \vec{L} = angular momentum (N·m·s)
Angular/Rotational Energy, Work & Power	$K_r = \frac{1}{2}I\omega^2$ $K = K_t + K_r = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$ $W_r = \tau\Delta\theta$ $P = \frac{W}{t} = \tau\omega$	

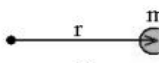
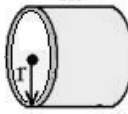
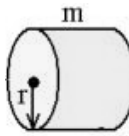
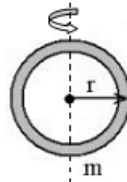
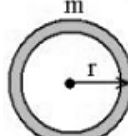
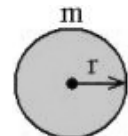
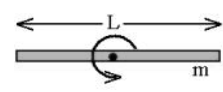
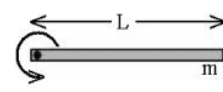
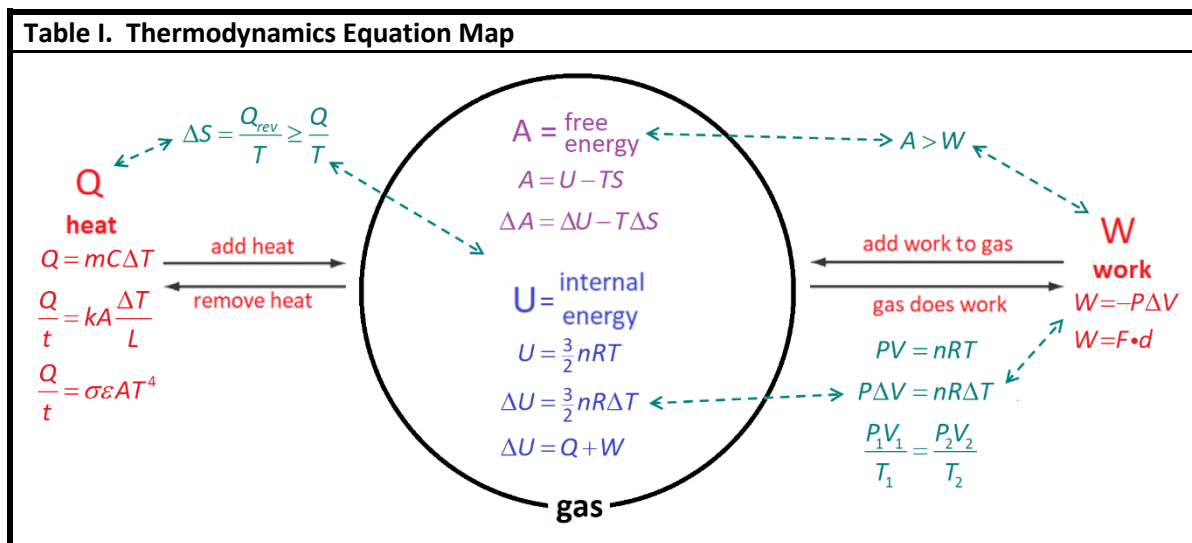
Table G. Moments of Inertia			
 Point Mass: $I = mr^2$	 Hollow Cylinder: $I = mr^2$	 Solid Cylinder: $I = \frac{1}{2}mr^2$	 Hoop About Diameter: $I = \frac{1}{2}mr^2$
 Hollow Sphere: $I = \frac{2}{3}mr^2$	 Solid Sphere: $I = \frac{2}{5}mr^2$	 Rod About the Middle: $I = \frac{1}{12}mL^2$	 Rod About the End: $I = \frac{1}{3}mL^2$

Table H. Heat and Thermal Physics Formulas and Equations		
<p>Temperature</p> $T_{°F} = 1.8(T_{°C}) + 32$ $T_K = T_{°C} + 273.15$	<p>Heat</p> $Q = mC\Delta T$ $Q_{melt} = m\Delta H_{fus}$ $Q_{boil} = m\Delta H_{vap}$ $C_p - C_v = R$ $\Delta L = \alpha L_i \Delta T$ $\Delta V = \beta V_i \Delta T$ $P = \frac{Q}{t} = (\pm) kA \frac{\Delta T}{L}$ $P = \frac{Q}{t} = \epsilon \sigma AT^4$ <p>(in this section, P = power)</p>	<p>Thermodynamics</p> $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ $PV = nRT = Nk_B T$ $P\Delta V = nR\Delta T = Nk_B \Delta T$ $\Delta U = Q + W$ $U = \frac{3}{2} nRT \quad \Delta U = \frac{3}{2} nR\Delta T$ $W = -P\Delta V = -\int_{V_1}^{V_2} P dV$ $K_{(molecular)} = \frac{3}{2} RT$ $U = \frac{3}{2} nRT = \frac{3}{2} Nk_B T$ $\Delta U = \frac{3}{2} nR\Delta T = \frac{3}{2} Nk_B \Delta T$ $v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_B T}{\mu}}$ $\Delta S = \frac{Q_{rev}}{T} \geq \frac{Q}{T}$ $A = U - TS$ $\Delta A = \Delta U - T\Delta S$ <p>(in this section, P = pressure)</p>
<p><i>var. = name of quantity (unit)</i></p> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>Δ = change in something (E.g., Δx = change in x)</p> <p>$T = T_K$ = Kelvin temperature (K)</p> <p>$T_{°F}$ = Fahrenheit temperature (°F)</p> <p>$T_{°C}$ = Celsius temperature (°C)</p> <p>Q = heat (J, kJ)</p> <p>m = mass (kg)</p> <p>C = specific heat capacity* ($\frac{kJ}{kg \cdot ^\circ C}, \frac{J}{g \cdot ^\circ C}$)</p> <p>$t$ = time (s)</p> <p>L = length (m)</p> <p>k = coefficient of thermal conductivity* ($\frac{J}{m \cdot s \cdot ^\circ C}, \frac{W}{m \cdot ^\circ C}$)</p> <p>$\epsilon$ = emissivity* (dimensionless)</p> <p>H_{fus} = latent heat of fusion ($\frac{kJ}{kg}, \frac{J}{g}$)</p> <p>$H_{vap}$ = heat of vaporization ($\frac{kJ}{kg}, \frac{J}{g}$)</p> <p>$\sigma$ = Stefan-Boltzmann constant $= 5.67 \times 10^{-8} \frac{W}{m^2 \cdot s \cdot K^4}$</p> <p>$V$ = volume (m^3)</p> <p>α = linear coefficient of thermal expansion* ($^\circ C^{-1}$)</p> <p>β = volumetric coefficient of thermal expansion* ($^\circ C^{-1}$)</p> <p>P = power (W)</p> </div> <div style="width: 45%;"> <p>P = pressure (Pa)</p> <p>n = number of moles (mol)</p> <p>N = number of molecules</p> <p>R = gas constant = $8.31 \frac{J}{mol \cdot K}$</p> <p>$k_B$ = Boltzmann constant $= 1.38 \times 10^{-23} \frac{J}{K}$</p> <p>$U$ = internal energy (J)</p> <p>W = work (J, N·m)</p> <p>v_{rms} = root mean square speed ($\frac{m}{s}$)</p> <p>μ = molecular mass* (kg)</p> <p>M = molar mass* ($\frac{kg}{mol}$)</p> <p>K = kinetic energy (J)</p> <p>Q_{rev} = "reversible" heat (J)</p> <p>S = entropy ($\frac{J}{K}$)</p> <p>A = Helmholtz free energy (J)</p> </div> </div> <p>*characteristic property of a substance (to be looked up)</p>		



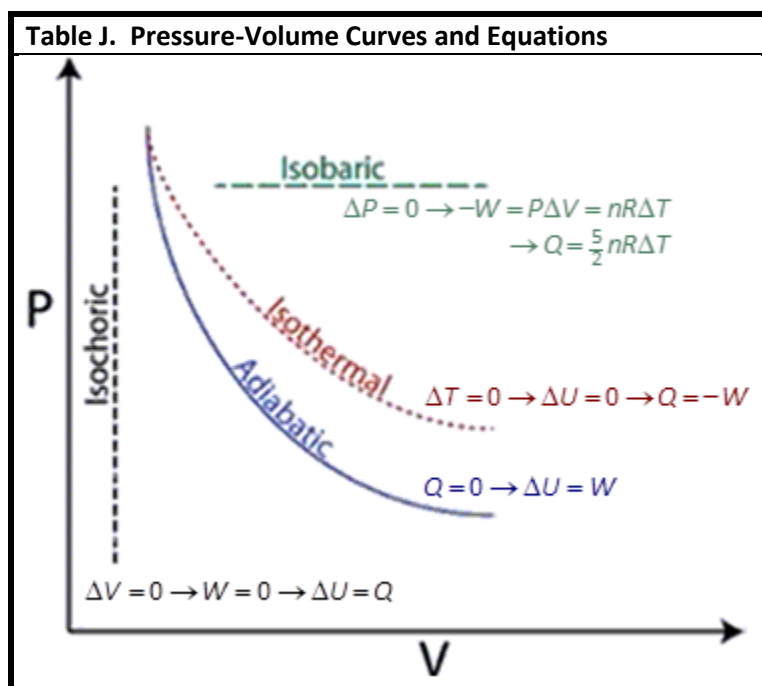


Table K. Thermal Properties of Selected Materials

Substance	Melting Point (°C)	Boiling Point (°C)	Heat of Fusion ΔH_{fus} ($\frac{kJ}{kg}, \frac{J}{g}$)	Heat of Vaporization ΔH_{vap} ($\frac{kJ}{kg}, \frac{J}{g}$)	Specific Heat Capacity C ($\frac{kJ}{kg \cdot ^\circ C}$) at 25°C	Thermal Conductivity k ($\frac{J}{ms \cdot ^\circ C}$) at 25°C	Emissivity ϵ black body = 1	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	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*	$\sim 3 \times 10^{-5}$	8.9×10^{-5}
steam (gas) @ 100°C	—	—	—	—	2.080	0.016	—	—	—
water (liq.) @ 25°C	0	100	—	2260	4.181	0.58	0.95	6.9×10^{-5}	2.07×10^{-4}
ice (solid) @ -10°C	—	—	334	—	2.11	2.18	0.97	—	—

*polished surface

Table L. Electricity Formulas & Equations		<i>var. = name of quantity (unit)</i>
Electrostatic Charges & Electric Fields	$\vec{F}_e = \frac{kq_1q_2}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{q_1q_2}{r^2}$ $\vec{E} = \frac{\vec{F}_e}{q} = \frac{Q}{\epsilon_0 A} \quad \vec{E} = \frac{kq}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} = \frac{\Delta V}{\Delta r}$ $W = q\vec{E} \cdot \vec{d} = qEd_{\parallel} = qEd \cos\theta$ $\Delta V = \frac{W}{q} = \vec{E} \cdot \vec{d} = Ed_{\parallel} = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$ $\Delta U_E = q\Delta V \quad U_E = \frac{kq_1q_2}{r}$	<p>Δ = change in something. (E.g., Δx = change in x)</p> <p>\vec{F}_e = force due to electric field (N)</p> <p>ϵ_0 = electric permittivity of a vacuum</p> $= 8.85 \times 10^{-12} \frac{A^2 \cdot s^4}{kg \cdot m^3}$ <p>k = electrostatic constant</p> $= \frac{1}{4\pi\epsilon_0} = 9.0 \times 10^9 \frac{N \cdot m^2}{C^2}$ <p>q = point charge (C)</p> <p>Q = charge (C)</p> <p>\vec{E} = electric field $\left(\frac{N}{C}, \frac{V}{m}\right)$</p> <p>$V$ = electric potential (V)</p> <p>ΔV = voltage = electric potential difference (V)</p> <p>\mathcal{E} = emf = electromotive force (V)</p> <p>W = work (J, N·m)</p> <p>$\kappa = \epsilon_r$ = relative permittivity* (<i>dimensionless</i>)</p> <p>d = distance (m)</p> <p>r = radius (m)</p> <p>\vec{I} = current (A)</p> <p>t = time (s)</p> <p>R = resistance (Ω)</p> <p>P = power (W)</p> <p>ρ = resistivity ($\Omega \cdot m$)</p> <p>L = length (m)</p> <p>A = cross-sectional area (m^2)</p> <p>C = capacitance (F)</p> <p>U = potential energy (J)</p> <p>π = pi (mathematical constant)</p> <p>= 3.14159 26535 89793...</p> <p>e = Euler's number (mathematical constant)</p> <p>= 2.78182 81812 84590...</p>
Circuits and Electrical Components	$\Delta V = IR \quad I = \frac{\Delta Q}{\Delta t} = \frac{\Delta V}{R}$ $\mathcal{E} = IR$ $P = I\Delta V = I^2R = \frac{(\Delta V)^2}{R}$ $W = Pt = I\Delta Vt$ $R = \frac{\rho L}{A}$ $C = \kappa\epsilon_0 \frac{A}{d}$ $Q = C\Delta V$ $U_{capacitor} = \frac{1}{2}Q\Delta V = \frac{1}{2}C(\Delta V)^2$ $P_{total} = P_1 + P_2 + P_3 + \dots = \sum P_i$ $U_{total} = U_1 + U_2 + U_3 + \dots = \sum U_i$	
Series Circuits (or Series Sections of Circuits)	$I_{total} = I_1 = I_2 = I_3 = \dots$ $\Delta V_{total} = \Delta V_1 + \Delta V_2 + \Delta V_3 + \dots = \sum \Delta V_i$ $R_{equiv.} = R_1 + R_2 + R_3 + \dots = \sum R_i$ $Q_{total} = Q_1 = Q_2 = Q_3 = \dots$ $\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots = \sum \frac{1}{C_i}$	
Parallel Circuits (or Parallel Sections of Circuits)	$I_{total} = I_1 + I_2 + I_3 + \dots = \sum I_i$ $\Delta V_{total} = \Delta V_1 = \Delta V_2 = \Delta V_3 = \dots$ $\frac{1}{R_{equiv.}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots = \sum \frac{1}{R_i}$ $Q_{total} = Q_1 + Q_2 + Q_3 + \dots = \sum Q_i$ $C_{total} = C_1 + C_2 + C_3 + \dots = \sum C_i$	
Resistor-Capacitor (RC) Circuits	<p>charging: $\frac{I}{I_0} = e^{-t/RC}$</p> <p>charging: $\frac{Q}{Q_{max}} = 1 - e^{-t/RC}$</p> <p>discharging: $\frac{I}{I_0} = \frac{V}{V_0} = \frac{Q}{Q_{max}} = e^{-t/RC}$</p>	<p>*characteristic property of a substance (to be looked up)</p>

Table M. Electricity & Magnetism Formulas & Equations		
Magnetism and Electro-magnetism	$\vec{F}_M = q(\vec{v} \times \vec{B}) \quad F_M = qvB \sin \theta$ $\vec{F}_M = \ell(\vec{I} \times \vec{B}) \quad F_M = \ell IB \sin \theta$ $\Delta V = \ell(\vec{v} \times \vec{B}) \quad \Delta V = \ell vB \sin \theta$ $B = \frac{\mu_0 I}{2\pi r}$ $\Phi_B = \vec{B} \cdot \vec{A} = BA \cos \theta$ $\mathcal{E} = \frac{\Delta \Phi_B}{\Delta t} = BLv$	<p>var. = name of quantity (unit)</p> <p>Δ = change in something. (E.g., Δx = change in x)</p> <p>\vec{F}_e = force due to electric field (N)</p> <p>\vec{v} = velocity (of moving charge or wire) ($\frac{m}{s}$)</p> <p>q = point charge (C)</p> <p>ΔV = voltage = electric potential difference (V)</p> <p>\mathcal{E} = emf = electromotive force (V)</p> <p>r = radius (m) = distance from wire</p> <p>\vec{I} = current (A)</p> <p>L = length (m)</p> <p>t = time (s)</p> <p>A = cross-sectional area (m^2)</p> <p>\vec{B} = magnetic field (T)</p> <p>μ_0 = magnetic permeability of a vacuum = $4\pi \times 10^{-7} \frac{T \cdot m}{A}$</p> <p>$\Phi_B$ = magnetic flux ($T \cdot m^2$)</p>
	Electro-magnetic Induction	$\frac{\#turns_{in}}{\#turns_{out}} = \frac{V_{in}}{V_{out}} = \frac{I_{out}}{I_{in}}$ $P_{in} = P_{out}$

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		$\pm 5\%$
silver		$\pm 10\%$

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 2000	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	$v = \lambda f$ $f = \frac{1}{T}$ $v_{\text{wave on a string}} = \sqrt{\frac{F_T}{\mu}}$ $f_{\text{doppler shifted}} = f \left(\frac{\vec{v}_{\text{wave}} + \vec{v}_{\text{detector}}}{\vec{v}_{\text{wave}} + \vec{v}_{\text{source}}} \right)$ $x = A \cos(2\pi ft + \phi)$	<i>var. = name of quantity (unit)</i> Δ = change in something (E.g., Δx = change in x) v = velocity of wave ($\frac{m}{s}$) \vec{v} = velocity of source or detector ($\frac{m}{s}$) 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 ($\frac{kg}{m}$)
Reflection, Refraction & Diffraction	$\theta_i = \theta_r$ $n = \frac{c}{v}$ $n_1 \sin \theta_1 = n_2 \sin \theta_2$ $\theta_c = \sin^{-1} \left(\frac{n_2}{n_1} \right)$ $\frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$ $\Delta L = m \lambda = d \sin \theta$	θ = angle ($^\circ$, rad) ϕ = phase offset ($^\circ$, rad) θ_i = angle of incidence ($^\circ$, rad) θ_r = angle of reflection ($^\circ$, rad) θ_c = critical angle ($^\circ$, rad) n = index of refraction* (<i>dimensionless</i>) c = speed of light in a vacuum = $3.00 \times 10^8 \frac{m}{s}$ $f = s_f = d_f$ = 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 (<i>dimensionless</i>) d = separation (m) L = distance from the opening (m) m = an integer
Mirrors & Lenses	$f = \frac{r_c}{2}$ $\frac{1}{s_i} + \frac{1}{s_o} = \frac{1}{f}$ $M = \frac{h_i}{h_o} = -\frac{s_i}{s_o}$	r_c = radius of curvature of spherical mirror (m) h_i = height of image (m) h_o = height of object (m) M = magnification (<i>dimensionless</i>) 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 $f = 5.89 \times 10^{14}$ 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

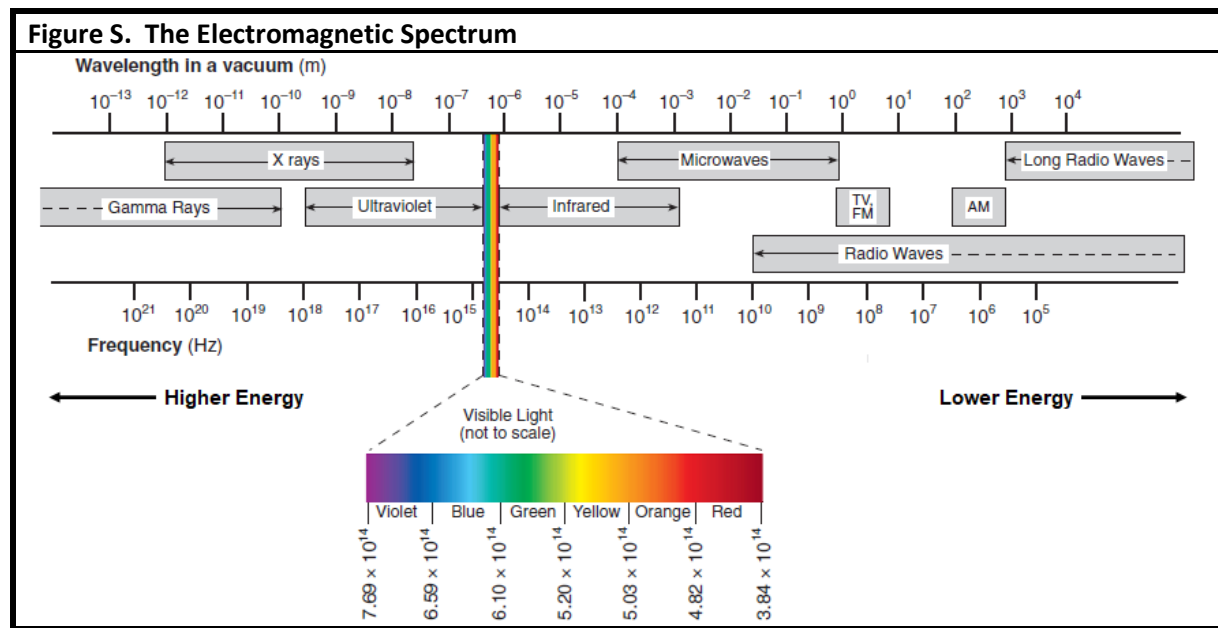


Table T. Planetary Data

	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 ($\frac{\text{kg}}{\text{m}^3}$)	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. ($^\circ\text{C}$)	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	$\rho = \frac{m}{V}$ $P = \frac{F}{A}$ $\frac{F_1}{A_1} = \frac{F_2}{A_2}$ $P_{\text{hydrostatic}} = P_H = \rho gh$ $F_B = \rho V_d g$ $P_{\text{dynamic}} = P_D = \frac{1}{2} \rho v^2$ $A_1 v_1 = A_2 v_2$ $P_{\text{total}} = P_{\text{ext.}} + P_H + P_D$ $P_1 + P_{H,1} + P_{D,1} = P_2 + P_{H,2} + P_{D,2}$ $P_1 + \rho gh_1 + \frac{1}{2} \rho v_1^2 = P_2 + \rho gh_2 + \frac{1}{2} \rho v_2^2$
	<i>var.</i> = name of quantity (unit) Δ = change in something. (E.g., Δx = change in x) ρ = density $\left(\frac{\text{kg}}{\text{m}^3}\right)$ <i>m</i> = mass (kg) <i>V</i> = volume (m^3) <i>P</i> = pressure (Pa) <i>g</i> = gravitational field = $9.8 \frac{\text{N}}{\text{kg}} \approx 10 \frac{\text{N}}{\text{kg}}$ <i>h</i> = height or depth (m) <i>A</i> = area (m^2) <i>v</i> = velocity (of fluid) $\left(\frac{\text{m}}{\text{s}}\right)$ <i>F</i> = 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	$E_{\text{photon}} = hf = \frac{hc}{\lambda} = pc = \hbar\omega$ $E_{k,\text{max}} = hf - \phi$ $\lambda = \frac{h}{p}$ $E_{\text{photon}} = E_i - E_f$ $E^2 = (pc)^2 + (mc^2)^2$ $\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$	<i>var.</i> = name of quantity (unit) Δ = change in something. (<i>E.g.</i> , Δx = change in x) E = energy (J) h = Planck's constant = 6.63×10^{-34} J·s \hbar = reduced Planck's constant = $\frac{h}{2\pi} = 1.05 \times 10^{-34}$ J·s f = frequency (Hz) v = velocity ($\frac{m}{s}$) c = speed of light = 3.00×10^8 $\frac{m}{s}$ λ = wavelength (m) p = momentum (N·s) m = mass (kg) K = kinetic energy (J) ϕ = work function* (J) R_H = Rydberg constant = 1.10×10^7 m ⁻¹ 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)
Special Relativity	$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ $\gamma = \frac{L_o}{L} = \frac{\Delta t'}{\Delta t} = \frac{m_{rel}}{m_o}$	*characteristic property of a substance (to be looked up)

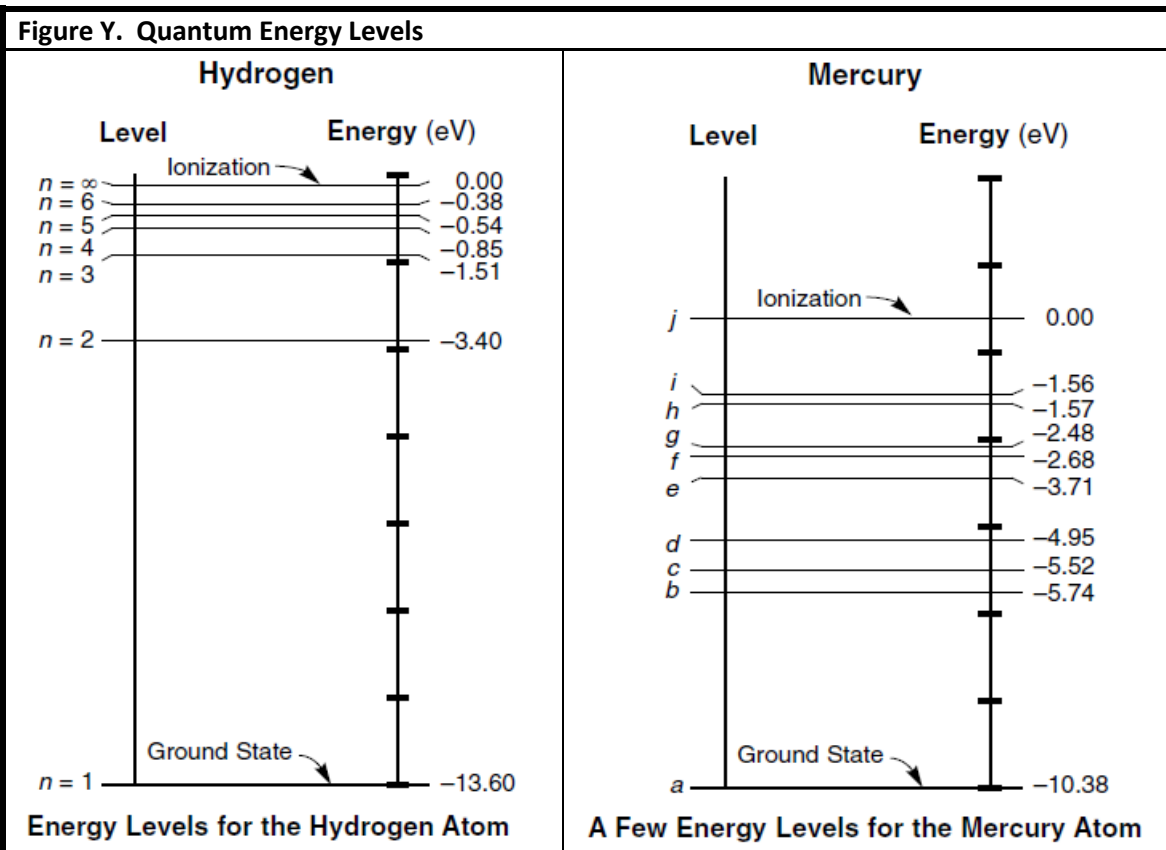


Figure Z. Particle Sizes

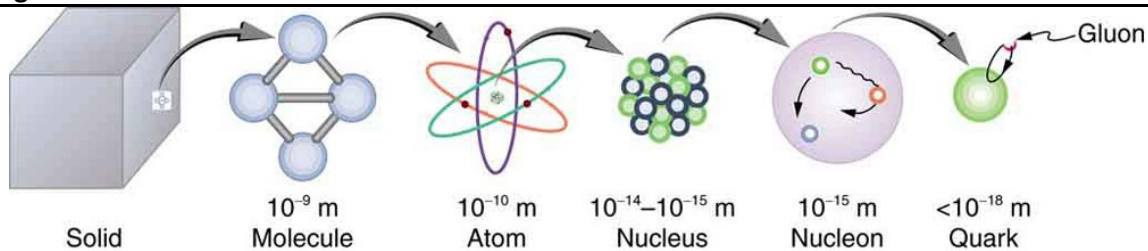


Figure AA. Classification of Matter

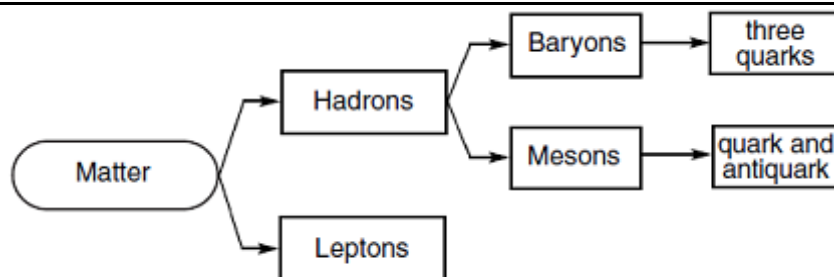


Table BB. The Standard Model of Elementary Particles

Standard Model of Elementary Particles

	three generations of matter (fermions)			interactions / force carriers (bosons)	
	I	II	III		
mass	$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$	0	$\approx 124.97 \text{ GeV}/c^2$
charge	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0	0
spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	0
QUARKS	u up	c charm	t top	g gluon	H higgs
	d down	s strange	b bottom	γ photon	
LEPTONS	e electron	μ muon	τ tau	Z Z boson	GAUGE BOSONS VECTOR BOSONS
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	SCALAR BOSONS
	$< 1.0 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 18.2 \text{ MeV}/c^2$	$\approx 91.19 \text{ GeV}/c^2$	
	0	0	0	0	
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	

Figure CC. Periodic Table of the Elements

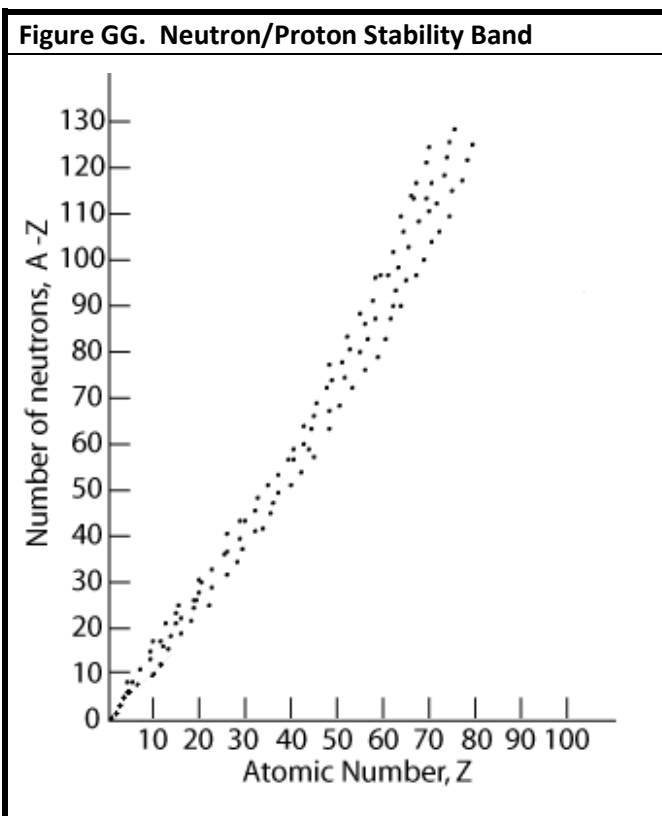
18 VIII A	2																	10	17	18																												
	He																	Ne	F	Ar																												
13 III A	5												6	7	8	9	16	17	18																													
	B												C	N	O	F	Cl	Ar																														
14 IV A	13											14	15	16	17	18	19	20																														
	Al											Si	P	S	Cl	Ar	Kr	Xe																														
15 V A	31										32	33	34	35	36	37	38																															
	Ga										Ge	As	Se	Br	Kr	Xe	Rn																															
16 VI A	49									50	51	52	53	54	55	56																																
	In									Sn	Sb	Te	I	Xe	Rn	Og																																
17 VII A	81								82	83	84	85	86	87	88																																	
	Tl								Pb	Bi	Po	At	Rn	Fr	Ra																																	
18 VIII A	113							114	115	116	117	118	119	120																																		
	Nh							Fl	Mc	Lv	Ts	Og	Uue	Uub																																		
19 II A	3																	4	11	12																												
	Li																	Be	B	C																												
20 II A	11																12	13	14																													
	Na																Mg	Al	Si																													
21 III B	19															20	21	22	23	24	25	26	27	28	29	30																						
	K															Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn																						
22 III B	37														38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54																	
	Rb														Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe																	
23 IV B	55													56	57	58	59	60	61	62	63	64	65	66	67	68	69	70																				
	Cs													Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb													
24 IV B	87												88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118					
	Fr												Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl

lanthanides
(rare earth metals)

actinides

Name	Notation	Symbol
alpha particle	${}^4_2\text{He}$ or ${}^4_2\alpha$	α
beta particle (electron)	${}^0_{-1}e$ or ${}^0_{-1}\beta$	β^-
gamma radiation	${}^0_0\gamma$	γ
neutron	1_0n	n
proton	${}^1_1\text{H}$ or 1_1p	p
positron	${}^0_{+1}e$ or ${}^0_{+1}\beta$	β^+

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)	3.7×10^{10} Bq



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

Table HH. Mathematics Formulas		
Scientific Notation	$3 \times 10^4 = 3 \times 10\,000 = 30\,000$ $2 \times 10^{-3} = 2 \times 0.001 = 0.002$ $(3 \times 10^4)(2 \times 10^{-3}) = (3 \cdot 2)(10^4 \cdot 10^{-3}) = 6 \times 10^{4+(-3)} = 6 \times 10^1 = 60$	
Rounding (to underlined place)	$15 \underline{3}54 \rightarrow 15 \underline{4}00$ $27 \underline{2}49.99 \rightarrow 27 \underline{2}00$ $0.037 \underline{5}00 \rightarrow 0.037 \underline{5}$	
Algebra with Fractions	$\frac{a}{b} + \frac{c}{d} = \frac{a \cdot d}{bd} + \frac{c \cdot b}{db} = \frac{ad+cb}{bd}$ $\frac{a \cdot c}{b \cdot d} = \frac{ac}{bd}$ $\frac{a}{b/c} = a \cdot \frac{c}{b}$ $\frac{a}{x} = b \rightarrow x \cdot \frac{a}{x} = b \cdot x \rightarrow a = bx \rightarrow \frac{a}{b} = \frac{bx}{b} \rightarrow \frac{a}{b} = x$	
Quadratic Equation	$ax^2 + bx + c = 0 \rightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$	
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	$S = 2\pi rL + 2\pi r^2 = 2\pi r(L + r)$ $V = \pi r^2 L$	
Spheres	$S = 4\pi r^2$ $V = \frac{4}{3}\pi r^3$	

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	≈	$\frac{1}{16}$ teaspoon (tsp.)
	1 dash	≈	$\frac{1}{8}$ 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
Temperature	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		
A	α	alpha
B	β	beta
Γ	γ	gamma
Δ	δ	delta
E	ε	epsilon
Z	ζ	zeta
H	η	eta
Θ	θ	theta
I	ι	iota
K	κ	kappa
Λ	λ	lambda
M	μ	mu
N	ν	nu
Ξ	ξ	xi
O	ο	omicron
Π	π	pi
P	ρ	rho
Σ	σ	sigma
T	τ	tau
Υ	υ	upsilon
Φ	φ	phi
X	χ	chi
Ψ	ψ	psi
Ω	ω	omega

Table LL. Decimal Equivalents	
$\frac{1}{2} = 0.5$	$\frac{2}{5} = 0.2$
$\frac{1}{3} = 0.33\bar{3}$	$\frac{3}{5} = 0.4$
$\frac{2}{3} = 0.66\bar{6}$	$\frac{4}{5} = 0.6$
$\frac{1}{4} = 0.25$	$\frac{6}{5} = 0.8$
$\frac{3}{4} = 0.75$	$\frac{7}{8} = 0.125$
$\frac{1}{6} = 0.166\bar{6}$	$\frac{8}{8} = 0.375$
$\frac{5}{6} = 0.833\bar{3}$	$\frac{9}{8} = 0.625$
$\frac{1}{7} = 0.142857\bar{}$	$\frac{10}{8} = 0.875$
$\frac{2}{7} = 0.285714\bar{}$	$\frac{11}{9} = 0.11\bar{1}$
$\frac{3}{7} = 0.428571\bar{}$	$\frac{12}{9} = 0.22\bar{2}$
$\frac{4}{7} = 0.571428\bar{}$	$\frac{13}{9} = 0.44\bar{4}$
$\frac{5}{7} = 0.714285\bar{}$	$\frac{14}{9} = 0.55\bar{5}$
$\frac{6}{7} = 0.857142\bar{}$	$\frac{15}{9} = 0.77\bar{7}$
$\frac{1}{11} = 0.0909\bar{}$	$\frac{16}{9} = 0.88\bar{8}$
$\frac{2}{11} = 0.1818\bar{}$	$\frac{1}{16} = 0.0625$
$\frac{3}{11} = 0.2727\bar{}$	$\frac{3}{16} = 0.1875$
$\frac{4}{11} = 0.3636\bar{}$	$\frac{5}{16} = 0.3125$
$\frac{5}{11} = 0.4545\bar{}$	$\frac{7}{16} = 0.4375$
$\frac{6}{11} = 0.5454\bar{}$	$\frac{9}{16} = 0.5625$
$\frac{7}{11} = 0.6363\bar{}$	$\frac{11}{16} = 0.6875$
$\frac{8}{11} = 0.7272\bar{}$	$\frac{13}{16} = 0.8125$
$\frac{9}{11} = 0.8181\bar{}$	$\frac{15}{16} = 0.9375$
$\frac{10}{11} = 0.9090\bar{}$	

