

# Physics Handbook

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2014-15

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## Rejection Quotient at Different Confidence Limits

Number of Observations	Q <sub>90</sub>	Q <sub>95</sub>	Q <sub>99</sub>
3	0.941	0.970	0.994
4	0.765	0.829	0.926
5	0.642	0.710	0.821
6	0.560	0.625	0.740
7	0.507	0.568	0.680
8	0.468	0.526	0.634
9	0.437	0.493	0.598
10	0.412	0.466	0.568

$$Q = \frac{|gap|}{range}$$

If  $Q > Q_{table}$  then the outlier is discarded.

Christian, Gary D. *Analytical Chemistry*, 5<sup>th</sup> ed.; John Wiley & Sons: New York, 1994; p 44.

## Percent Error

$$Percent\ error = \frac{observed\ value - true\ value}{true\ value} \times 100\%$$

## Percent Yield

$$Percent\ yield = \frac{actual\ yield}{theoretical\ yield} \times 100\%$$

## Orders of Magnitude

$10^{12}$	$10^9$	$10^6$	$10^3$	$10^2$	$10^1$	$10^0$	$10^{-1}$	$10^{-2}$	$10^{-3}$	$10^{-6}$	$10^{-9}$	$10^{-12}$	$10^{-15}$
tera	giga	mega	kilo	hecto	deca	No	deci	centi	milli	micro	nano	pico	femto
T	G	M	k	h	da	prefix	d	c	m	$\mu$	n	p	f

## Units of Measurement

SI base units are highlighted

<u>Quantity</u>	<u>Unit (Symbol)</u>	<u>Notes</u>
Acceleration	meters per second per second ( $\text{m/s}^2$ )	also $\text{m/s/s}$ or $\text{m}\cdot\text{s}^{-2}$
Activity	becquerel (Bq)	$1/\text{s} = \text{s}^{-1}$
Capacitance	farad (F)	$\text{C/V} = \text{kg}^{-1}\cdot\text{m}^{-2}\cdot\text{s}^4\cdot\text{A}^2$
Current	ampere (A)	
Electric Charge	coulomb (C)	$\text{A}\cdot\text{s}$
Electric Potential	volt (V)	$\text{W/A} = \text{kg}\cdot\text{m}^2\cdot\text{s}^{-3}\cdot\text{A}^{-1}$
Energy	calorie (cal)	metric unit
Energy/Work	joule (J)	$\text{J} = \text{kg}\cdot\text{m}^2\cdot\text{s}^{-2}$
Force	newton (N)	$\text{N} = \text{kg}\cdot\text{m}\cdot\text{s}^{-2}$
Frequency	hertz (Hz)	$\text{waves/s} = 1/\text{s} = \text{s}^{-1}$
Inductance	henry (H)	$\text{kg}\cdot\text{m}^2\cdot\text{s}^{-2}\cdot\text{A}^{-2}$
Length	meter (m)	
Luminous Intensity	candela (cd)	

<u>Quantity</u>	<u>Unit (Symbol)</u>	<u>Notes</u>
Magnetic Field	tesla (T)	$\text{T} = \text{kg}\cdot\text{s}^{-2}\cdot\text{A}^{-1}$
Magnetic Flux	weber (Wb)	$\text{Wb} = \text{kg}\cdot\text{m}^2\cdot\text{s}^{-2}\cdot\text{A}^{-1}$
Mass	gram (g)	Base unit is the kilogram (1000 g)
Momentum	newton second (N·s)	$\text{N}\cdot\text{s} = \text{kg}\cdot\text{m}\cdot\text{s}^{-1}$
Power	watt (W)	$\text{J/s} = \text{kg}\cdot\text{m}^2\cdot\text{s}^{-3}$
Pressure	pascal (Pa)	$\text{Pa} = \text{N/m}^2 = \text{kg}\cdot\text{m}\cdot\text{s}^{-2}$
Quantity	mole (mol)	
Resistance	ohm ( $\Omega$ )	$\text{V/A} = \text{kg}\cdot\text{m}^2\cdot\text{s}^{-3}\cdot\text{A}^{-2}$
Temperature	degree Celsius ( $^{\circ}\text{C}$ )	Metric unit based on $T_f$ and $T_b$ for water
Temperature	kelvin (K)	
Time	second (s)	
Velocity	meter per second (m/s)	
Volume	liter (L)	$1 \text{ L} = 1 \text{ dm}^3 = 0.001 \text{ m}^3$

## Formulas

$$v = \frac{d}{t}$$

$$d = v_0 t + \frac{1}{2} a t^2$$

$$v_f^2 = v_0^2 + 2ad$$

$$F = ma$$

$$p = mv$$

$$F = \frac{\Delta p}{\Delta t}$$

$$I = F \Delta t = m \Delta v$$

$$W = Fd \cos \theta$$

$$E_k = \frac{1}{2} m v^2 = \frac{p^2}{2m}$$

$$\Delta E_p = mg \Delta h$$

$$P = \frac{W}{t} = Fv$$

$$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$$

$$P = \frac{F}{A}$$

$$q = m C_p \Delta T = mL$$

$$\omega = \frac{2\pi}{T}$$

$$v = \pm \omega \sqrt{(x_0^2 - x^2)}$$

$$E_k = \frac{1}{2} m \omega^2 (x_0^2 - x^2)$$

$$E_T = \frac{1}{2} m \omega^2 x_0^2$$

$$v = f \lambda = \lambda \nu$$

$$\frac{n_1}{n_2} = \frac{\sin \theta_2}{\sin \theta_1} = \frac{v_2}{v_1}$$

$$V_e = \frac{1}{2} m v^2$$

$$I = \frac{\Delta q}{\Delta t}$$

$$R = \frac{V}{I} = \frac{\rho L}{A}$$

$$P = VI = I^2 R = \frac{V^2}{R}$$

$$\varepsilon = I(R + r)$$

$$R_T = R_1 + R_2 + \dots$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

$$F = G \frac{m_1 m_2}{r^2}$$

$$F = k \frac{q_1 q_2}{r^2}$$

$$F = \frac{q_1 q_2}{4\pi \varepsilon_0 r^2}$$

$$F = qvB \sin \theta$$

$$F = BIL \sin \theta$$

$$E = mc^2$$

# Constants and Conversion Factors

Avogadro's Number =  $6.022 \times 10^{23}$

Boltzmann's constant =  $1.38 \times 10^{-23} \text{ J K}^{-1}$

Coulomb's constant =  $8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$

Faraday constant =  $96485 \text{ C/mol e}^-$

Gas law constant =  $0.0821 \text{ atm L mol}^{-1} \text{ K}^{-1} = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$

Gravitational constant =  $6.67 \times 10^{-11} \text{ N kg}^{-2} \text{ m}^2$

Magnetic permeability =  $4\pi \times 10^{-7} \text{ T m A}^{-1}$

Magnitude of electric charge =  $1.60 \times 10^{-19} \text{ C}$

Planck's constant =  $6.626 \times 10^{-34} \text{ J} \times \text{s}$

Rydberg constant =  $1.0974 \times 10^7 \text{ m}^{-1}$

Speed of light =  $2.998 \times 10^8 \text{ m/s}$

Standard temperature and pressure is  $0^\circ\text{C}$  and 1 atm

At standard temperature and pressure, 1 mol of gas occupies 22.414 L

Stefan-Boltzmann constant =  $5.6704 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

$m_{\text{proton}} = 1.673 \times 10^{-27} \text{ kg}$

$m_{\text{electron}} = 9.109 \times 10^{-31} \text{ kg}$

$m_{\text{neutron}} = 1.675 \times 10^{-27} \text{ kg}$

$^\circ\text{F} = 1.8(^\circ\text{C}) + 32$

$\text{K} = ^\circ\text{C} + 273.15$

## Length

1 angstrom ( $\text{\AA}$ ) =  $1 \times 10^{-10}$  meters

1 inch = 2.54 centimeters

1 foot = 12 inches

1 meter = 3.2808 feet

1 yard = 3 feet

1 chain = 22 yards

1 furlong = 10 chains

1 mile = 5280 feet

1 mile = 1.609 kilometers

1 light year =  $9.46 \times 10^{15}$  meters

1 astronomical unit (AU) =  $1.50 \times 10^{11}$  m

1 parsec = 3.26 light years

1 degree =  $\pi/180$  radians

## Volume

1 gallon = 3.785 liters

1 gallon = 4 quarts

1 quart = 2 pints

1 pint = 2 cups

1 cup = 8 fluid ounces

1 fluid ounce = 29.575 mL

## Mass/Weight

1 atomic mass unit =  $1.6606 \times 10^{-27}$

kilograms

1 ounce = 28.35 grams

1 troy ounce = 31.103 grams

1 pound = 16 ounces

1 kilogram = 2.2046 pounds

1 stone = 14 pounds

## Pressure

1 atmosphere = 760 torr

1 atmosphere = 760 mm Hg

1 atmosphere = 101.325 kilopascals

1 atmosphere = 1013.25 millibars

1 atmosphere = 14.7 pounds per square inch (psi)

## Energy

1 calorie = 4.184 J

1 eV =  $1.602 \times 10^{-19}$  J

## Characteristic Properties of Common Substances

Substance	State of Matter	Density (g/cm <sup>3</sup> )	Specific Heat (J/g°C)	Melting Point (°C)	Boiling Point (°C)
Aluminum	Solid	2.6984	0.897	660.32	2519
Benzene	Liquid	0.879	1.74	5.49	80.09
Brass	Solid	8.875 <sup>a</sup>	0.380	1040	
Bromine	Liquid	3.119	0.226	-7.2	58.8
Copper	Solid	8.92	0.385	1084.62	2562
Ethanol	Liquid	0.789	2.44	-114.14	78.29
Gold	Solid	19.3	0.129	1064.18	2856
Graphite	Solid	2.2	0.709	4489 <sup>c</sup>	3825 <sup>d</sup>
Iodine	Solid	4.660	0.145	113.7	184.4
Iron	Solid	7.86	0.449	1538	2861
Isopropyl (Rubbing) Alcohol	Liquid	0.785	2.61	-87.9	82.3
Lead	Solid	11.34	0.129	327.46	1749
Magnesium	Solid	1.74	1.023	650	1090
Manganese	Solid	7.30	0.479	1246	2061
Maple	Solid	0.62-0.75			
Mercury	Liquid	13.5336	0.140	-38.837 <sup>c</sup>	356.73
Methanol	Liquid	0.7914	2.53	-97.6	64.6
Nickel	Solid	8.90	0.444	1455	2913
Oak	Solid	0.60-0.90			
(White) Pine	Solid	0.35-0.50			
Polyvinyl Chloride (PVC)	Solid	1.39-1.42			
Silicon	Solid	2.3290	0.705	1414	3265
Silver	Solid	10.50	0.235	961.78	2162
Stainless Steel	Solid	7.75		1510	
Tin	Solid	7.28 <sup>b</sup>	0.228	231.93	2602
Titanium	Solid	4.507	0.523	1668	3287
Tungsten	Solid	19.35	0.132	3422	5555
Zinc	Solid	7.14	0.338	419.53	907

<sup>a</sup>– average value    <sup>b</sup>– white    <sup>c</sup>– triple point    <sup>d</sup>–sublimation point

Dean, John A. *Lange's Handbook of Chemistry*, 11<sup>th</sup> ed.; McGraw-Hill: New York, New York, 1979; p 3-2 – 3-5, 7-54 –7-393, 11-19 – 11-26.

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Lide, David R. *CRC Handbook*, 84<sup>th</sup> ed.; CRC Press: Boca Raton, Florida, 2004; pp 4-132, 4-133, 5-5 – 5-60, 6-7, 6-13, 15-32.

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Tipler, Paul A. *Physics for Scientists and Engineers*, 4<sup>th</sup> ed., W.H. Freeman, 1999

# Half-Lives and Masses for Selected Nuclides

All masses (third column) are given in amu

$^1_0\text{n}$	614 s	1.00866
$^3_1\text{H}$	12.33 d	3.01605
$^4_2\text{H}$	$1.9 \times 10^{-22}$ s	4.02781
$^5_1\text{H}$	$8 \times 10^{-23}$ s	5.03531
$^6_1\text{H}$	$3 \times 10^{-22}$ s	6.04494
$^6_2\text{He}$	0.805 s	6.01889
$^7_4\text{Be}$	53.28 d	7.01693
$^8_3\text{Li}$	0.844 s	8.02249
$^9_5\text{B}$	$8 \times 10^{-19}$ s	9.01333
$^{10}_4\text{Be}$	$1.52 \times 10^6$ y	10.01353
$^{10}_6\text{C}$	19.3 s	10.01685
$^{11}_6\text{C}$	20.3 m	11.01143
$^{12}_5\text{B}$	0.0204 s	12.01435
$^{14}_6\text{C}$	5715 y	14.00324
$^{15}_6\text{C}$	2.45 s	15.01060
$^{15}_8\text{O}$	124 s	15.00307
$^{18}_9\text{F}$	1.82951 h	18.00094
$^{22}_{11}\text{Na}$	950.97 d	21.99444
$^{24}_{11}\text{Na}$	14.9512 h	23.99096
$^{31}_{14}\text{Si}$	2.62 h	30.97536
$^{32}_{15}\text{P}$	14.28 d	31.97391
$^{33}_{17}\text{Cl}$	2.511 s	32.97745
$^{33}_{18}\text{Ar}$	174 ms	32.98993
$^{35}_{16}\text{S}$	87.2 d	34.96903
$^{40}_{19}\text{K}$	$1.26 \times 10^9$ y	39.96400
$^{41}_{18}\text{Ar}$	1.82 h	40.96450
$^{44}_{22}\text{Ti}$	22154 d	43.95969
$^{46}_{21}\text{Sc}$	83.831 d	45.95517
$^{51}_{24}\text{Cr}$	27.7010 d	50.94477
$^{54}_{25}\text{Mn}$	312.028 d	53.94036
$^{55}_{26}\text{Fe}$	2.73 y	54.93829
$^{57}_{27}\text{Co}$	272.11 d	56.93629
$^{58}_{27}\text{Co}$	70.77 d	57.93575
$^{59}_{26}\text{Fe}$	44.5074 d	58.93488
$^{59}_{29}\text{Cu}$	1.36 m	58.93950
$^{62}_{29}\text{Cu}$	9.67 m	61.93258
$^{64}_{29}\text{Cu}$	12.701 h	63.92976
$^{65}_{30}\text{Zn}$	244.164 d	64.92924
$^{67}_{31}\text{Ga}$	3.26154 d	66.92820
$^{74}_{34}\text{As}$	17.8 d	73.92393

$^{75}_{34}\text{Se}$	119.809 d	74.92252
$^{77}_{33}\text{As}$	38.8 h	76.92065
$^{77}_{37}\text{Rb}$	3.8 m	76.93041
$^{78}_{38}\text{Y}$	5.8 s	77.94361
$^{79}_{34}\text{Se}$	$1.1 \times 10^6$ y	78.91850
$^{82}_{35}\text{Br}$	1.471 d	81.91680
$^{82}_{38}\text{Sr}$	25.36 d	81.91840
$^{85}_{36}\text{Kr}$	3934.4 d	84.91253
$^{85}_{38}\text{Sr}$	64.8530 d	84.91293
$^{87}_{37}\text{Rb}$	$4.9 \times 10^{10}$ y	86.90918
$^{88}_{39}\text{Y}$	106.626 d	87.90950
$^{90}_{38}\text{Sr}$	29.1 y	89.90774
$^{98}_{43}\text{Tc}$	$4.2 \times 10^6$ y	97.90722
$^{99}_{42}\text{Mo}$	65.9239 h	98.90771
$^{101}_{42}\text{Mo}$	14.6 m	100.91035
$^{105}_{41}\text{Nb}$	3.0 s	104.92394
$^{109}_{48}\text{Cd}$	463.26 d	108.90498
$^{110}_{47}\text{Ag}$	249.950 d	109.90611
$^{111}_{49}\text{In}$	2.80477 d	110.90510
$^{113}_{50}\text{Sn}$	115.079 d	112.90517
$^{115}_{49}\text{In}$	$5 \times 10^{14}$ y	114.90388
$^{116}_{47}\text{Ag}$	2.68 m	115.91137
$^{117}_{50}\text{Sn}$	14.00 d	116.90295
$^{123}_{53}\text{I}$	13.2235 h	122.90559
$^{123}_{52}\text{Te}$	$2.4 \times 10^{19}$ y	122.90427
$^{125}_{53}\text{I}$	59.49 d	124.90463
$^{125}_{51}\text{Sb}$	1007.56 d	124.90525
$^{127}_{54}\text{Xe}$	36.3446 d	126.90518
$^{131}_{53}\text{I}$	8.0197 d	130.90612
$^{131}_{54}\text{Xe}$	11.934 d	130.90508
$^{133}_{56}\text{Ba}$	3853.6 d	132.90601
$^{133}_{57}\text{La}$	3.91 h	132.90822
$^{133}_{54}\text{Xe}$	5.24747 d	132.90591
$^{134}_{55}\text{Cs}$	753.88 d	133.90672
$^{137}_{55}\text{Cs}$	11015 d	136.90709
$^{139}_{56}\text{Ba}$	1.396 h	138.90884
$^{139}_{58}\text{Ce}$	137.734 d	138.90665
$^{140}_{56}\text{Ba}$	12.7527 d	139.91061
$^{140}_{57}\text{La}$	40.293 h	139.90948
$^{141}_{58}\text{Ce}$	32.50 d	140.90828



<sup>144</sup> Ce	284.558 d	143.91365
<sup>144</sup> Nd	5 × 10 <sup>15</sup> y	143.91009
<sup>148</sup> Dy	3.1 m	147.92715
<sup>149</sup> Sm	4 × 10 <sup>14</sup> y	148.91718
<sup>152</sup> Eu	4945.5 d	151.92174
<sup>153</sup> Gd	239.472 d	152.92175
<sup>153</sup> Sm	46.2853 h	152.92210
<sup>154</sup> Eu	3138.2 d	153.92298
<sup>154</sup> Tb	21.5 h	153.92469
<sup>155</sup> Eu	1738.97 d	154.92289
<sup>166</sup> Ho	26.7663 h	165.93228
<sup>169</sup> Yb	32.0147 d	168.93519
<sup>176</sup> Hg	21 ms	175.98736
<sup>177</sup> Lu	6.64 d	176.94376
<sup>181</sup> Au	11.4 s	180.97008
<sup>181</sup> W	121.095 d	180.94820
<sup>183</sup> Ir	57 m	182.95685
<sup>185</sup> Pt	1.18 h	184.96062
<sup>186</sup> Os	2 × 10 <sup>15</sup> y	185.95384
<sup>186</sup> Re	89.248 h	185.95499
<sup>187</sup> Re	7 × 10 <sup>10</sup> y	186.95575
<sup>188</sup> Ir	1.72 d	187.95885
<sup>188</sup> Re	17.021 h	187.95811
<sup>190</sup> Pt	6.1 × 10 <sup>11</sup> y	189.95993
<sup>192</sup> Ir	73.810 d	191.96261
<sup>195</sup> Au	186.098 d	194.96503
<sup>198</sup> Au	2.69517 d	197.96824
<sup>201</sup> Tl	3.0456 d	200.97082
<sup>202</sup> Tl	12.466 d	201.97211
<sup>203</sup> Hg	46.619 d	202.97287
<sup>203</sup> Pb	51.923 h	202.97339
<sup>204</sup> Pb	1.4 × 10 <sup>17</sup> y	203.97304
<sup>205</sup> Pb	1.51 × 10 <sup>7</sup> y	204.97448
<sup>207</sup> Bi	11523 d	206.97847
<sup>208</sup> Po	2.898 y	207.98125
<sup>212</sup> Bi	60.6 m	211.99129
<sup>213</sup> At	0.11 μs	212.99294
<sup>214</sup> Po	1.637 × 10 <sup>-4</sup> s	213.99520
<sup>214</sup> Pa	17 ms	214.02093
<sup>218</sup> At	1.6 s	218.00869
<sup>218</sup> Po	3.0 m	218.00897
<sup>218</sup> Th	0.11 μs	218.01328
<sup>219</sup> Pa	0.05 μs	219.01989
<sup>222</sup> Rn	3.82 d	222.01758

<sup>223</sup> Ra	11.7 d	223.01850
<sup>224</sup> Ra	3.64 d	224.02021
<sup>225</sup> Ra	14.8 d	225.02361
<sup>226</sup> Ra	1620 y	226.02541
<sup>228</sup> Ra	6.7 y	228.03107
<sup>228</sup> Th	698.60 d	228.02874
<sup>230</sup> Th	8 × 10 <sup>4</sup> y	230.03313
<sup>231</sup> U	4.2 d	231.03629
<sup>232</sup> Th	1.40 × 10 <sup>10</sup> y	232.03806
<sup>232</sup> Pa	1.31 d	232.03859
<sup>232</sup> U	72 y	232.03716
<sup>233</sup> Pa	27 d	233.04025
<sup>233</sup> U	1.6 × 10 <sup>5</sup> y	233.03964
<sup>233</sup> Pu	20.9 m	233.04301
<sup>234</sup> Pa	6.69 h	234.04331
<sup>234</sup> U	2.4 × 10 <sup>5</sup> y	234.04095
<sup>235</sup> Pa	24.4 m	235.04545
<sup>235</sup> U	7.05 × 10 <sup>8</sup> y	235.04393
<sup>235</sup> Np	1.085 y	235.04406
<sup>237</sup> U	6.75 d	237.04873
<sup>237</sup> Pu	45.7 d	237.04841
<sup>238</sup> U	4.46 × 10 <sup>9</sup> y	238.05079
<sup>239</sup> Np	2.355 d	239.05294
<sup>239</sup> Pu	2.41 × 10 <sup>4</sup> y	239.05216
<sup>241</sup> Am	432.7 y	241.05683
<sup>241</sup> Cm	32.8 d	241.05765
<sup>242</sup> Bk	7.0 m	242.06198
<sup>244</sup> Bk	4.4 h	244.06518
<sup>245</sup> Pu	10.5 h	245.06775
<sup>250</sup> Bk	3.217 h	250.07832
<sup>251</sup> Cf	9.0 × 10 <sup>2</sup> y	251.07959
<sup>255</sup> Fm	20.1 h	255.08996
<sup>257</sup> Fm	100.5 d	257.09511
<sup>258</sup> Md	56 d	258.09843
<sup>260</sup> Lr	3 m	260.10550
<sup>261</sup> Bh	12 ms	261.12166
<sup>261</sup> Rf	1.1 m	261.10877
<sup>268</sup> Mt	0.07 s	268.13873

Lide, David R. *CRC Handbook*, 83<sup>rd</sup> ed., CRC Press: Boca Raton, Florida, 2002; p 11-51 – 11-213.

# The Electromagnetic Spectrum

EMR	Frequencies (Hz)		Wavelength (m)		Notes
Military communication	3.00E+03	3.00E+04	9993.33	99933.33	Radio
Navigation/Time	3.00E+04	3.00E+05	999.33	9993.33	
AM radio (long wave - Europe)	1.53E+05	2.79E+05	1074.55	1959.48	
AM radio (medium wave - North America)	5.35E+05	1.70E+06	176.35	560.37	
AM radio (short wave - international)	5.90E+06	2.61E+07	11.49	50.81	
Citizens band radio	2.696E+07	2.741E+07	10.94	11.12	
Garage door openers	4.000E+07		7.50		
Cordless phones	4.000E+07	5.000E+07	6.00	7.50	
Baby monitors	4.900E+07		6.12		
Television (network) stations 2 through 6*	5.40E+07	8.80E+07	3.41	5.55	
Radio controlled airplanes	7.200E+07		4.16		
Radio controlled cars	7.500E+07		4.00		
FM radio	8.80E+07	1.08E+08	2.78	3.41	
Television (network) stations 7 through 13*	1.74E+08	2.20E+08	1.36	1.72	
Wildlife tracking collars	2.150E+08	2.200E+08	1.36	1.39	
Cell phones	8.240E+08	8.490E+08	0.353	0.364	
Air traffic control	9.600E+08	1.215E+09	0.247	0.312	
GPS (Global Positioning System)	1.227E+09		0.24		
GPS (Global Positioning System)	1.58E+09		0.19		
Deep space radio communication	2.290E+09	2.300E+09	0.1303	0.1309	

<b>EMR</b>	<b>Frequencies (Hz)</b>		<b>Wavelength (m)</b>		<b>Notes</b>
Microwaves - microwave oven	2.450E+09		0.12		<b>Microwave</b>
Microwaves - ultra-high frequency (UHF)	3.000E+08	3.000E+09	0.0999	0.9993	
Microwaves - super high frequency (SHF)	3.000E+09	3.000E+10	0.0100	0.0999	
Microwaves - extremely high frequency (EHF)	3.000E+10	3.000E+11	0.0010	0.0100	
Far infrared (FIR)	3.00E+11	2.00E+13	1.5E-05	1.0E-03	<b>Infrared</b>
Long wavelength infrared (LWIR)	2.00E+13	3.75E+13	8.0E-06	1.5E-05	
Mid wavelength infrared (MWIR)	3.75E+13	9.99E+13	3.0E-06	8.0E-06	
Short wavelength infrared (SWIR)	9.99E+13	2.14E+14	1.4E-06	3.0E-06	
Near infrared (NIR)	2.14E+14	4.00E+14	7.5E-07	1.4E-06	
Red	4.00E+14	4.84E+14	6.20E-07	7.50E-07	<b>Visible Light</b>
Orange	4.84E+14	5.08E+14	5.90E-07	6.20E-07	
Yellow	5.08E+14	5.26E+14	5.70E-07	5.90E-07	
Green	5.26E+14	6.06E+14	4.95E-07	5.70E-07	
Blue	6.06E+14	6.66E+14	4.50E-07	4.95E-07	
Violet	6.66E+14	7.89E+14	3.80E-07	4.50E-07	
Near ultraviolet (UVA or long wave/"blacklight")	7.89E+14	9.52E+14	3.15E-07	3.80E-07	<b>Ultraviolet</b>
Near ultraviolet (UVB or medium wave)	9.52E+14	1.07E+15	2.80E-07	3.15E-07	
Near ultraviolet (UVC or short wave)	1.07E+15	1.50E+15	2.00E-07	2.80E-07	
Extreme or Vacuum ultraviolet	1.50E+15	3.00E+16	1.00E-08	2.00E-07	
X-rays	3.00E+16	3.00E+18	1.00E-10	1.00E-08	X-rays
Gamma rays	2.42E+18	...and up	1.24E-10	...and shorter	Gamma rays


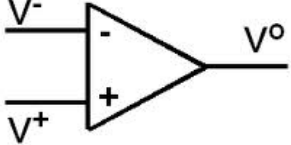

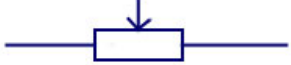
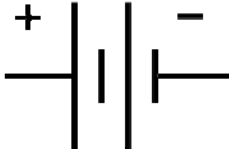
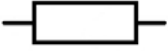

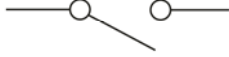
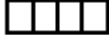



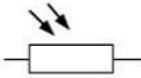
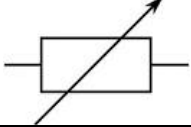
## Astronomical Data for Selected Celestial Objects

<b>Body (Orbits)</b>	<b>Radius (km)</b>	<b>Volume (10<sup>9</sup> km<sup>3</sup>)</b>	<b>Mass (10<sup>24</sup> g)</b>	<b>Orbital period (d)</b>	<b>Orbital distance* (km)</b>
Ariel (Uranus)	578.9	0.81	1.35	2.520	190900
Callisto (Jupiter)	2410	58.65	107.6	16.689	1882700
Ceres	476.2	0.437	0.95	1679.785	413700000
Charon (Pluto)	604	0.87	1.52	6.387	17536
Dione (Saturn)	561.4	0.73	1.096	2.737	377396
Earth	6371	1083.21	5973.6	365.256	149597890
Eris	1163	7	16.7	203444.250	1021000000
Europa (Jupiter)	1560.8	15.93	48	3.551	670900
Ganymede (Jupiter)	2634.1	76.3	148.2	7.155	1070400
Iapetus (Saturn)	735	1.55	1.9739	79.322	3560820
Io (Jupiter)	1821.6	25.32	89.3	1.769	421600
Jupiter	69911	1431280	1898600	4332.820	778412010
Makemake	715	1.7	3	113190.975	685000000
Mars	3389.5	163.18	641.85	686.980	227936640
Mercury	2440	60.83	330.2	87.969	57909175
Moon	1737.1	21.958	73.5	27.322	384399
Neptune	24622	62540	102430	60190.030	4498252900
Oberon (Uranus)	761	1.85	3.014	13.460	583519
Pluto	1184	6.39	13.105	90577.809	590638000
Rhea (Saturn)	764	1.87	2.3166	4.518	527108
Saturn	58232	827130	568460	10755.699	1426725400
Sun	696000	1412000000	1989000000		
Tethys (Saturn)	531.1	0.624	0.6173	1.888	294619
Titan (Saturn)	2576	71.52	134.5	15.945	1221870
Titania (Uranus)	788.4	2.06	3.526	8.706	436300
Triton (Neptune)	1353.4	10.38	21.5	5.877	354759
Umbriel (Uranus)	585	0.84	1.2	4.144	266000
Uranus	25362	68340	86832	30687.153	2870972200
Venus	6052	928.43	4868.5	224.701	108208930

\* – average

Lide, David R. *CRC Handbook, 83<sup>rd</sup> ed.*; CRC Press: Boca Raton, Florida, 2002; pp 14-3 – 14-5.

# Electrical Circuit Symbols

AC supply		operational amplifier	
ammeter		potentiometer	
battery		resistor	
cell		switch	
heating element		thermistor	
lamp		transformer	
light-dependent resistor (LDR)		variable resistor	
		voltmeter	