THE
HANDBOOK
FOR
PHYSICS AND CHEMISTRY
DRAFT #1

Periodic Table of the Elements

hydrogen 1 H 1.0079																	helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122											boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305											aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 **	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	ununnunium 111 Uuu [272]	unumbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
**Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

General Information

Table 1. Useful Data

Constant	Description	Value
M_e	Mass of Earth	5.98×10^{24} kg
R_e	Radius of Earth	6.37×10^{6} m
g	Freefall acceleration on Earth	9.80 m/s^2
G	Gravitational constant	6.67×10^{-11} N·m^2/kg^2
k_B	Boltzmann's Constant	1.38×10^{-23} J/K
R	Gas constant	8.314 J / mol·K
N_A	Avogadro's number	6.02×10^{23} parts/mol
T_0	Absolute Zero	-273° C
σ	Stefan-Boltzmann constant	5.67×10^{-8} W/m^2·K^4
p_{atm}	Standard atmosphere	101300 Pa
v_{sound}	Speed of sound in air (20° C)	343 m/s
m_e	Mass of electron	9.11×10^{-31} kg
m_p	Mass of proton	1.67×10^{-27} kg
m_n	Mass of neutron	1.67×10^{-27} kg
K	Coulomb's law constant	8.99×10^{9} M·m^2/C^2
ϵ_0	Permittivity constant	8.85×10^{-12} C^2/N·m^2
μ_0	Permeability constant	1.26×10^{-6} T·m/A
e	Fundamental unit of charge	1.60×10^{-19} C
c	Speed of light in vacuum	3.00×10^{8} m/s
h	Planck's constant	6.63×10^{-34} J·s
$\bar{h}$	Planck's constant	1.05×10^{-34} J·s
a_B	Bohr radius	5.29×10^{-11} m

Units and Conversions

Table 2. Common Prefixes

Prefix	Symbol	Multiplier
yocto-	y	10^{-24}
zepto-	z	10^{-23}
atto-	a	10^{-18}
femto-	f	10^{-15}
pico-	p	10^{-12}
nano-	n	10^{-9}
micro-	μ	10^{-6}
milli-	m	10^{-3}
centi-	c	10^{-2}
kilo-	k	10^{3}
mega-	M	10^{6}
giga-	G	10^{9}
tera-	T	10^{12}
peta-	P	10^{15}
exa-	E	10^{18}
zeta-	Z	10^{21}
yotta-	Y	10^{24}

Table 3. Conversion Factors

Length	
1 in	2.54 cm
1 mi	1.609 km
1 m	39.37 in
1 km	0.621 mi
Velocity	
1 mph	0.447 m/s
1 m/s	2.24 mph
Energy	
1 cal	4.186 J
1 eV	1.60×10^{-19} J
Times	
1 day	86400 s
1 year	3.16×10^{7} s
Pressure	
1 atm	101.3 kPa
1 atm	14.7 psi
1 atm	760 mmHg
Rotation	
1 rad	180°/π
1 rev	360°

Symbols

Table 4. Greek Letters

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

Table #. Value of Some numbers

Number	Value
π	3.1415927
e	2.7182818
$\sqrt{2}$	1.4142136
$\sqrt{3}$	1.7320508
ln 2	0.6931472
ln 10	2.3025851
log e	0.4342945

Derived Units in SI

Table 5. Derive Units for Physics

Quantity	Unit	Abbreviation	Base Unit
Area	–	–	m^2
Volume	–	–	m^3
Density	–	–	kg/m^3
Force	newton	N	$kg \cdot m/s^2$
Energy and Work	joule	J	$kg \cdot m^2/s^2$
Power	watt	W	$kg \cdot m^2/s^3$
Pressure	pascal	Pa	$kg/(m \cdot s^2)$
Frequency	hertz	Hz	s^{-1}
Electric Charge	coulomb	C	$A \cdot s$
Electric Potential	volt	V	$kg \cdot m^2/(A \cdot s^3)$
Electric Resistance	ohm	Ω	$kg \cdot m^2/(A^2 \cdot s^3)$
Capacitance	farad	F	$A^2 \cdot s^4/(kg \cdot m^2)$
Magnetic Field	tesla	T	$kg/(A \cdot s^2)$
Magnetic Flux	weber	Wb	$kg \cdot m^2/(A \cdot s^2)$
Inductance	henry	H	$kg \cdot m^2/(A^2 \cdot s^2)$

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

Physical Properties

Table. Density

Material	State	Density [kg/m^3]
Air (20° C)	Gas	1.293
Water	Liquid	~1000
Ice	Solid	920
Sea Water	Liquid	~1030
blood	Liquid	1600
Ethanol	Liquid	810
THF	Liquid	889
Mercury	Liquid	13600
Magnesium	Solid	1700
Aluminum	Solid	2700
Diamond	Solid	3500
Steel / Iron	Solid	7800
Brass	Solid	8600
Copper	Solid	8960
Lead	Solid	11300

Table. Heat Capacity

Material	State	Heat Capacity [kJ/kg·K^{-1}]
Air (20° C)	Gas	1.012
Water	Liquid	4.186
Ice	Solid	2.05
Ammonia	Liquid	4.700
Ethanol	Liquid	2.42
Mercury	Liquid	0.1395
Magnesium	Solid	1.02
Aluminum	Solid	0.903
Diamond	Solid	0.5091
Iron	Solid	0.449
Steel	Solid	0.466
Polyethylene	Solid	2.30
Copper	Solid	0.385
Lead	Solid	0.128
Gold	Solid	0.128
Silver	Solid	0.235
Glass (Pyrex)	Solid	0.75
Granite	Solid	0.79
Sand	Solid	0.84

Table. Vapor Pressure of water

Temperature [° C]	**Vapor Pressure [torr]**	**Vapor Pressure [kPa]**
0	4.58	0.610
10	9.21	1.23
20	17.54	2.34
30	31.82	4.24
40	55.3	7.37
50	92.5	12.3
60	149.4	19.9
70	233.7	31.2
80	355.1	47.3
90	525.8	70.1
100	760	101.3
110	1074.6	143.4

Chemical Properties

Table. Heat of Vaporization

Material	Normal B.P. [° C]	ΔH_{vap} at B.P. [kJ/mol]	ΔH_{vap} at 25° C [kJ/mol]
Water, H_2O	100	40.7	44.0
Rubbing Alcohol, C_3H_8O	82.3	39.9	45.4
Acetone, C_3H_6O	56.1	29.1	31.0
Diethyl Ether, $C_4H_{10}O$	34.6	26.5	27.1

Table. Heat of Fusion

Material	Normal M.P. [° C]	ΔH_{fus} [kJ/mol]
Water, H_2O	0	6.02
Rubbing Alcohol, C_3H_8O	-89.5	5.37
Acetone, C_3H_6O	-94.8	5.69
Diethyl Ether, $C_4H_{10}O$	-116.3	7.27

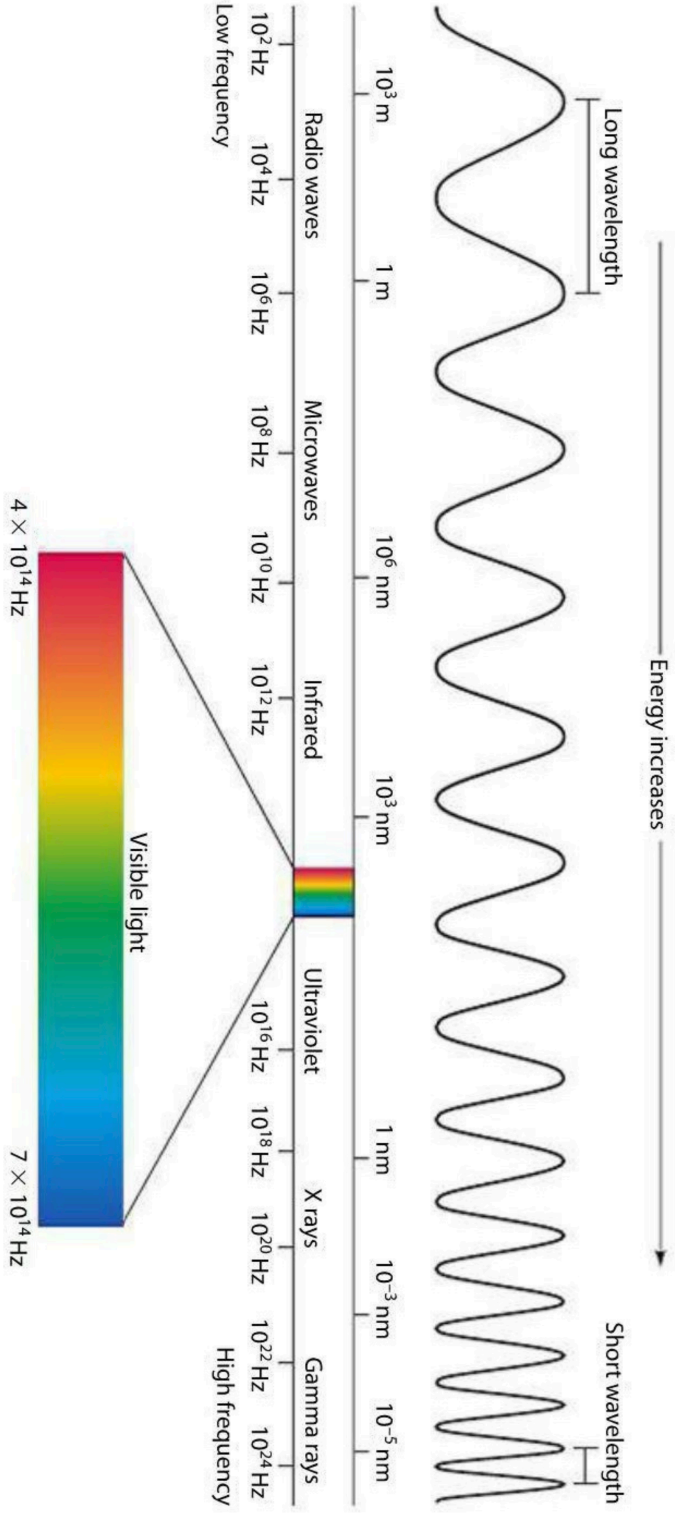
Table. Bond Energy

Bond	Bond Energy [kJ/mol]	Bond	Bond Energy [kJ/mol]	Bond	Bond Energy [kJ/mol]
$H-H$	436	$N-N$	163	$Br-F$	237
$H-C$	414	$N=N$	418	$Br-Cl$	218
$H-N$	389	$N\equiv N$	946	$Br-Br$	193
$H-O$	464	$N-O$	222	$I-Cl$	208
$H-S$	368	$N=O$	590	$I-Br$	175
$H-F$	565	$N-F$	272	$I-I$	151
$H-Cl$	431	$N-Cl$	200	$Si-H$	323
$H-Br$	364	$N-Br$	243	$Si-Si$	226
$H-I$	297	$N-I$	159	$Si-C$	301
$C-C$	347	$O-O$	142	$S-O$	265
$C=C$	611	$O=O$	498	$Si=O$	368
$C\equiv C$	837	$O-F$	190	$S=O$	523
$C-N$	305	$O-Cl$	203	$Si-Cl$	464
$C=N$	615	$O-I$	234	$S=S$	418
$C\equiv N$	891	$F-F$	159	$S-F$	327
$C-O$	360	$Cl-F$	253	$S-Cl$	253
$C=O$	736	$Cl-Cl$	243	$S-Br$	218
$C\equiv O$	1072			$S-S$	266
$C-Cl$	339				

Table. Standard Enthalpies of formation at 298K.

Formula	ΔH_f^o **[kJ/mol]**	ΔG_f^o **[kJ/mol]**	ΔS_f^o **[J/mol·K]**
Br (g)	111.9	82.4	175.0
Br_2 (l)	0	0	152.2
HBr (l)	-36.3	-53.4	198.7
Ca (s)	0	0	41.6
CaO (s)	-634.9	-603.3	38.1
$CaCO_3$ (s)	-1207.6	-1129.1	91.7
C (s, graphite)	0	0	5.7
C (s, diamond)	1.88	2.9	2.4
CO (g)	-110.5	-137.2	197.7
CO_2 (g)	-393.5	-394.4	213.8
CH_4 (g)	-74.6	-50.5	186.3
CH_3OH (l)	-238.6	-166.6	126.8
C_2H_2 (g)	227.4	209.9	200.9
C_2H_4 (g)	52.4	68.4	219.3
C_2H_6 (g)	-84.68	-32.0	229.2
C_2H_5OH (l)	-277.6	-174.8	160.7
C_3H_8 (g)	-103.85	-23.4	270.3
C_3H_6O (l, acetone)	-248.4	-155.6	199.8
C_3H_8O (l, isopropanol)	-318.1		181.1
C_6H_6 (l)	49.1	124.5	173.4
$C_6H_{12}O_6$ (s, glucose)	-1273.3	-910.4	212.1
$C_{12}H_{22}O_{11}$ (s, sucrose)	-2226.1	-1544.3	360.24
Cl (g)	121.3	105.3	165.2
Cl_2 (g)	0	0	223.1
HCl (g)	-92.3	-95.3	186.9
F (g)	79.38	62.3	158.75
F_2 (g)	0	00	202.79
HF (g)	-273.3	-275.4	173.8
H (g)	218.0	203.3	114.7
H_2 (g)	0	0	130.7
N_2 (g)	0	0	191.6
NH_3 (g)	-45.9	-16.4	192.8
NH_4NO_3 (s)	-365.6	-183.9	151.1
NO (g)	91.3	87.6	210.8
N_2O (g)	81.6	103.7	220.0
O_2 (g)	0	0	205.2
O_3 (g)	142.7	163.2	238.9
H_2O (g)	-241.8	-228.6	188.8
H_2O (l)	-285.5	-237.1	70.0
Ag (s)	0	0	42.6
AgCl (s)	-127.0	-109.8	96.3
Na (s)	0	0	51.3
Na (g)	107.5	77.0	153.7
NaCl (s)	-411.2	-384.1	72.1
Na_2CO_3 (s)	-1130.7	-1044.4	135.0
NaHCO3 (s)	-950.8	-851.0	101.7
S_8 (s, rhombic)	0	0	32.1
S_8 (s, monoclinic)	0.3	0.096	32.6
SO_2 (g)	-296.8	-300.1	248.2
SO_3 (g)	-395.7	-371.1	256.8
H_2SO_4 (l)	-814.0	-690.0	156.9

Electromagnetic Spectrum



Standard Reduction Potentials of Half-Cells

(Ionic concentrations are at 1M in water @ 25^0 C)

Increasing Strength of Oxidizing Agents ↑

Oxidizing Agents		Reducing Agents	E^0 (Volts)
$F_2(g) + 2e^-$	→	$2F^-(aq)$	+2.87
$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$	→	$PbSO_4(s) + 2H_2O(\ell)$	+1.69
$MnO_4^-(aq) + 8H^+(aq) + 5e^-$	→	$Mn^{2+}(aq) + 4H_2O(\ell)$	+1.51
$Au^{3+}(aq) + 3e^-$	→	$Au(s)$	+1.50
$ClO_4^-(aq) + 8H^+(aq) + 8e^-$	→	$Cl^-(aq) + 4H_2O(\ell)$	+1.39
$Cl_2(g) + 2e^-$	→	$2Cl^-(aq)$	+1.36
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^-$	→	$2Cr^{3+}(aq) + 7H_2O(\ell)$	+1.33
$2HNO_2(aq) + 4H^+(aq) + 4e^-$	→	$N_2O(g) + 3H_2O(\ell)$	+1.30
$O_2(g) + 4H^+(aq) + 4e^-$	→	$2H_2O(\ell)$	+1.23
$MnO_2(s) + 4H^+(aq) + 2e^-$	→	$Mn^{2+}(aq) + 2H_2O(\ell)$	+1.22
$Br_2(aq) + 2e^-$	→	$2Br^-(aq)$	+1.07
$Hg^{2+}(aq) + 2e^-$	→	$Hg(\ell)$	+0.85
$ClO^-(aq) + H_2O(\ell) + 2e^-$	→	$Cl^-(aq) + 2OH^-(aq)$	+0.84
$Ag^+(aq) + e^-$	→	$Ag(s)$	+0.80
$NO_3^-(aq) + 2H^+(aq) + e^-$	→	$NO_2(g) + H_2O(\ell)$	+0.80
$Fe^{3+}(aq) + e^-$	→	$Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^-$	→	$H_2O_2(\ell)$	+0.70
$I_2(s) + 2e^-$	→	$2I^-(aq)$	+0.54
$O_2(g) + 2H_2O(\ell) + 4e^-$	→	$4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^-$	→	$Cu(s)$	+0.34
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$	→	$H_2SO_3(aq) + H_2O(\ell)$	+0.17
$Sn^{4+}(aq) + 2e^-$	→	$Sn^{2+}(aq)$	+0.15
$S(s) + 2H^+(aq) + 2e^-$	→	$H_2S(aq)$	+0.14
$AgBr(s) + e^-$	→	$Ag(s) + Br^-(aq)$	+0.07
$2H^+(aq) + 2e^-$	→	$H_{2(g)}$	0.00
$Pb^{2+}(aq) + 2e^-$	→	$Pb(s)$	-0.13
$Sn^{2+}(aq) + 2e^-$	→	$Sn(s)$	-0.14
$AgI(s) + e^-$	→	$Ag(s) + I^-(aq)$	-0.15
$Ni^{2+}(aq) + 2e^-$	→	$Ni(s)$	-0.26
$Co^{2+}(aq) + 2e^-$	→	$Co(s)$	-0.28
$PbSO_4(s) + 2e^-$	→	$Pb(s) + SO_4^{2-}(aq)$	-0.36
$Se(s) + 2H^+(aq) + 2e^-$	→	$H_2Se(aq)$	-0.40
$Cd^{2+}(aq) + 2e^-$	→	$Cd(s)$	-0.40
$Cr^{3+}(aq) + e^-$	→	$Cr^{2+}(aq)$	-0.41
$Fe^{2+}(aq) + 2e^-$	→	$Fe(s)$	-0.45
$NO_2^-(aq) + H_2O(\ell) + e^-$	→	$NO(g) + 2OH^-(aq)$	-0.46
$Ag_2S(s) + 2e^-$	→	$2Ag(s) + S^{2-}(aq)$	-0.69
$Zn^{2+}(aq) + 2e^-$	→	$Zn(s)$	-0.76
$2H_2O(\ell) + 2e^-$	→	$H_2(g) + 2OH^-(aq)$	-0.83
$Cr^{2+}(aq) + 2e^-$	→	$Cr(s)$	-0.91
$Se(s) + 2e^-$	→	$Se^{2-}(aq)$	-0.92
$SO_4^{2-}(aq) + H_2O(\ell) + 2e^-$	→	$SO_3^{2-}(aq) + 2OH^-(aq)$	-0.93
$Al^{3+}(aq) + 3e^-$	→	$Al(s)$	-1.66
$Mg^{2+}(aq) + 2e^-$	→	$Mg(s)$	-2.37
$Na^+(aq) + e^-$	→	$Na(s)$	-2.71
$Ca^{2+}(aq) + 2e^-$	→	$Ca(s)$	-2.87
$Ba^{2+}(aq) + 2e^-$	→	$Ba(s)$	-2.91
$Li^+(aq) + e^-$	→	$Li(s)$	-3.04

Increasing Strength of Reducing Agents ↓

Kinematics

$$\vec{a} = \vec{a}(t)$$
$$\vec{v} = \int \vec{a}\, dt$$
$$\vec{x} = \iint \vec{a}\, dt = \int \vec{v}\, dt$$

$$\vec{a} = \frac{d^2\vec{x}}{dt^2} = \frac{d\vec{v}}{dt}$$
$$\vec{v} = \frac{d\vec{x}}{dt}$$
$$\vec{x} = \vec{x}(t)$$

$$s = r\theta$$
$$\omega = \frac{d\theta}{dt}$$
$$v_t = \frac{ds}{dt} = \omega r$$
$$a = \frac{v^2}{r} = \omega^2 r$$
$$\alpha = \frac{d\omega}{dt}$$

Mechanics

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \cdots = \sum \vec{F}_i$$
$$\vec{F} = m\vec{a} = \frac{d\vec{p}}{dt}$$
$$f_i = \mu_i n$$
$$\vec{D} = \left(\frac{1}{2} C\rho A v^2, opposite\right)$$
$$\vec{F}_{AB} = \vec{F}_{BA}$$
$$\vec{p} = m\vec{v}$$
$$\Delta p_x = \int F_x\,(t)\, dt$$
$$\vec{P} = \vec{p}_1 + \vec{p}_2 + \cdots = \sum \vec{p}_i$$
$$\vec{P}_f = \vec{P}_i$$
$$K = \frac{1}{2} m v^2$$
$$U_g = mgh$$
$$F = -k\Delta s$$
$$U_s = \frac{1}{2} k\,(\Delta s)^2$$
$$E_{sys} =$$
$$P = \frac{dE_{sys}}{dt}$$

Calculus

$$\frac{d}{dt}(ct^n) = nct^{n-1}$$

$$\frac{d}{dt}(u + w) = \frac{du}{dt} + \frac{dw}{dt}$$

Vectors

$$\vec{C} = \vec{A} + \vec{B}$$

$$C = \sqrt{A^2 + B^2}$$

$$\theta = \tan^{-1}\left(\frac{B}{A}\right)$$

$$\vec{A} = A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k}$$