Physics

Formula and data book



Formulas

Processing of data

Percentage uncertainty (%) =
$$\frac{\text{absolute uncertainty}}{\text{measurement}} \times 100$$

Percentage error (%) =
$$\left| \frac{\text{measured value} - \text{true value}}{\text{true value}} \right| \times 100$$

Heating processes

$$T_{\rm K} = T_{\rm C} + 273$$

$$Q = mL$$

$$Q = mc\Delta T$$

$$\Delta U = Q + W$$

$$\eta = \frac{\text{energy output}}{\text{energy input}} \times \frac{100}{1}\%$$

Ionising radiation and nuclear reactions

$$N = N_0 \left(\frac{1}{2}\right)^n$$

$$\Delta E = \Delta mc^2$$

Electrical circuits

$$I = \frac{q}{4}$$

$$P = I^2 R$$

$$V = \frac{W}{q}$$

$$V_t = V_1 + V_2 + \dots V_n$$

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

$$R_t = R_1 + R_2 + \cdots R_n$$

$$R = \frac{V}{I}$$

$$I_t = I_1 + I_2 + \dots I_n$$

$$P = VI$$

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

Linear motion and force	
v = u + at	$W = \Delta E$
$s = ut + \frac{1}{2}at^2$	W = Fs
$v^2 = u^2 + 2as$	$E_{\mathbf{k}} = \frac{1}{2}mv^2$
$a = \frac{F_{\text{net}}}{m}$	$\Delta E_{\mathrm{p}} = mg\Delta h$
p = mv	$\sum \frac{1}{2} m v_{\text{before}}^2 = \sum \frac{1}{2} m v_{\text{after}}^2$
$\sum mv_{ m before} = \sum mv_{ m after}$	

Waves	
$v = f\lambda$	$L = (2n-1)\frac{\lambda}{4}$
$f = \frac{1}{T}$	$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$
$L = n\frac{\lambda}{2}$	$I \propto \frac{1}{r^2}$

Gravity and motion	
$v_y = gt + u_y$	$v = \frac{2\pi r}{T}$
$s_y = \frac{1}{2}gt^2 + u_y t$	$a_{\rm C} = \frac{v^2}{r}$
$v_y^2 = 2gs_y + u_y^2$	$F_{\text{net}} = \frac{mv^2}{r}$
$v_x = u_x$	$F = \frac{GMm}{r^2}$
$s_x = u_x t$	$g = \frac{F}{m} = \frac{GM}{r^2}$
$F_g = mg$	$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$

Electromagnetism	
$F = \frac{1}{4\pi\varepsilon_0} \frac{Qq}{r^2}$	$F = qvB\sin\theta$
$E = \frac{F}{q} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2}$	$\phi = BA\cos\theta$
$V = \frac{\Delta U}{q}$	$emf = -\frac{n\Delta(BA_{\perp})}{\Delta t}$
$B = \frac{\mu_0 I}{2\pi r}$	$\mathrm{emf} = -n\frac{\Delta\phi}{\Delta t}$
$B = \mu_0 nI$	$I_{\rm p}V_{\rm p}=I_{\rm s}V_{\rm s}$
$F = BIL\sin\theta$	$\frac{V_{\rm p}}{V_{\rm s}} = \frac{n_{\rm p}}{n_{\rm s}}$

Special relativity	
$t = \frac{t_0}{\sqrt{(1 - \frac{v^2}{c^2})}}$	$p_{v} = \frac{m_{0}v}{\sqrt{(1 - \frac{v^{2}}{c^{2}})}}$
$L = L_0 \sqrt{(1 - \frac{v^2}{c^2})}$	$\Delta E = \Delta m c^2$

Quantum theory	
$\lambda_{\max} = \frac{b}{T}$	$\lambda = \frac{h}{p}$
E = hf	$n\lambda = 2\pi r$
$E_{\rm k} = hf - W$	$mvr = \frac{nh}{2\pi}$
$\frac{1}{\lambda} = R(\frac{1}{n_f^2} - \frac{1}{n_i^2})$	

Physical constants and unit conversions

Heating processes	
Latent heat of fusion for water	$L_{\rm f} = 3.34 \times 10^5 \mathrm{J kg^{-1}}$
Latent heat of vaporisation for water	$L_{\rm v} = 2.26 \times 10^6 \rm J kg^{-1}$
Specific heat capacity of ice	$c_{\rm i} = 2.05 \times 10^3 \mathrm{J kg^{-1} K^{-1}}$
Specific heat capacity of steam	$c_{\rm s} = 2.00 \times 10^3 \rm J kg^{-1} K^{-1}$
Specific heat capacity of water	$c_{\rm w} = 4.18 \times 10^3 \rm J kg^{-1} K^{-1}$

Ionising radiation and nuclear reactions	
Atomic mass unit	$1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg}$
Electron volt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$
Mass of an alpha particle	$m_{\alpha} = 6.6446572 \times 10^{-27} \text{kg}$
Mass of an electron	$m_{\rm e} = 9.1093835 \times 10^{-31} \rm kg$
Mass of a neutron	$m_{\rm n} = 1.6749275 \times 10^{-27} \rm kg$
Mass of a proton	$m_{\rm p} = 1.6726219 \times 10^{-27} {\rm kg}$
Speed of light in a vacuum	$c = 3 \times 10^8 \mathrm{m s^{-1}}$

Electrical circuits	
Charge on an electron	$e = -1.60 \times 10^{-19} \mathrm{C}$

Linear motion and force	
Mean acceleration due to gravity on Earth	$g = 9.8 \text{ m s}^{-2}$

Waves	
Speed of sound in air at 25 °C	$v_{\rm s} = 346 {\rm m s^{-1}}$

Gravity and motion	
Gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
Mass of the Earth	$m_{\rm E} = 5.97 \times 10^{24} {\rm kg}$

Electromagnetism	
Coulomb's constant	$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
Magnetic constant	$\mu_0 = 4\pi \times 10^{-7} T A^{-1} \mathrm{m}$

Quantum theory						
Wien's displacement constant	$b = 2.898 \times 10^{-3} \text{ m K}$					
Planck's constant	$h = 6.626 \times 10^{-34} \mathrm{J s}$					
Rydberg's constant	$R = 1.097 \times 10^7 \text{m}^{-1}$					

Scientific notation

Ratio to basic unit	Prefix	Abbreviation
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10 ⁻⁹	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d
10	deca	da
10^2	hecto	h
10^3	kilo	k
10 ⁶	mega	M
109	giga	G
10 ¹²	tera	Т

List of elements by name

Name	Atomic no.	Symbol
Hydrogen	1	Н
Helium	2	Не
Lithium	3	Li
Beryllium	4	Be
Boron	5	В
Carbon	6	С
Nitrogen	7	N
Oxygen	8	О
Fluorine	9	F
Neon	10	Ne
Sodium	11	Na
Magnesium	12	Mg
Aluminium	13	Al
Silicon	14	Si
Phosphorus	15	P
Sulfur	16	S
Chlorine	17	Cl
Argon	18	Ar
Potassium	19	K
Calcium	20	Ca
Scandium	21	Sc
Titanium	22	Ti
Vanadium	23	V
Chromium	24	Cr
Manganese	25	Mn
Iron	26	Fe
Cobalt	27	Со
Nickel	28	Ni
Copper	29	Cu
Zinc	30	Zn

Name	Atomic no.	Symbol			
Gallium	31	Ga			
Germanium	32	Ge			
Arsenic	33	As			
Selenium	34	Se			
Bromine	35	Br			
Krypton	36	Kr			
Rubidium	37	Rb			
Strontium	38	Sr			
Yttrium	39	Y			
Zirconium	40	Zr			
Niobium	41	Nb			
Molybdenum	42	Mo			
Technetium	43	Tc			
Ruthenium	44	Ru			
Rhodium	45	Rh			
Palladium	46	Pd			
Silver	47	Ag			
Cadmium	48	Cd			
Indium	49	In			
Tin	50	Sn			
Antimony	51	Sb			
Tellurium	52	Те			
Iodine	53	I			
Xenon	54	Xe			
Cesium	55	Cs			
Barium	56	Ba			
Lanthanum	57	La			
Cerium	58	Се			
Praseodymium	59	Pr			
Neodymium	60	Nd			

Name	Atomic no.	Symbol				
Promethium	61	Pm				
Samarium	62	Sm				
Europium	63	Eu				
Gadolinium	64	Gd				
Terbium	65	Tb				
Dysprosium	66	Dy				
Holmium	67	Но				
Erbium	68	Er				
Thulium	69	Tm				
Ytterbium	70	Yb				
Lutetium	71	Lu				
Hafnium	72	Hf				
Tantalum	73	Та				
Tungsten	74	W				
Rhenium	75	Re				
Osmium	76	Os				
Iridium	77	Ir				
Platinum	78	Pt				
Gold	79	Au				
Mercury	80	Hg				
Thallium	81	Tl				
Lead	82	Pb				
Bismuth	83	Bi				
Polonium	84	Po				
Astatine	85	At				
Radon	86	Rn				
Francium	87	Fr				
Radium	88	Ra				
Actinium	89	Ac				
Thorium	90	Th				

Name	Atomic no.	Symbol
Protactinium	91	Pa
Uranium	92	U
Neptunium	93	Np
Plutonium	94	Pu
Americium	95	Am
Curium	96	Cm
Berkelium	97	Bk
Californium	98	Cf
Einsteinium	99	Es
Fermium	100	Fm
Mendelevium	101	Md
Nobelium	102	No
Lawrencium	103	Lr
Rutherfordium	104	Rf
Dubnium	105	Db
Seaborgium	106	Sg
Bohrium	107	Bh
Hassium	108	Hs
Meitnerium	109	Mt
Darmstadtium	110	Ds
Roentgenium	111	Rg
Copernicium	112	Cn
Nihonium	113	Nh
Flerovium	114	Fl
Moscovium	115	Mc
Livermorium	116	Lv
Tennessine	117	Ts
Oganesson	118	Og

Periodic table of the elements

1																	18
\mathbf{H}^{-1}					1	Ato	mic numbe	er									110
1.01	2		H ← Symbol 13 14 15 16 17										He 4.00				
3	4]			1.01←	→ Rela	ative atom	ic mass*			[5	6	7	8	9	10
Li	Be											В	\mathbf{C}	\mathbf{N}	\mathbf{o}	\mathbf{F}	Ne
6.94	9.01											10.81	12.01	14.01	16.00	19.00	20.18
11	12											13	14	15	16	17	18
Na	$\mathbf{M}\mathbf{g}$											Al	Si	P	S	Cl	Ar
22.99	24.31	3	4	5	6	7	8	9	10	11	12	26.98	28.09	30.97	32.06	35.45	39.95
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.10	40.08	44.96	47.87	50.94	52.00	54.94	55.85	58.93	58.69	63.55	65.38	69.72	72.63	74.92	78.97	79.90	83.80
37 Dh	38	39	4 0	41 NIL	42 N/I	43 To	P	45 DL	46 D.J	47	48	49 T	50	51 Sh	52 To	53	V 54
Rb 85.47	Sr 87.62	Y 88.91	Zr 91.22	Nb 92.91	Mo 95.95	Tc (98.91)	Ru 101.07	Rh	Pd 106.42	Ag 107.87	Cd	In 114.82	Sn	Sb	Te	I 126.90	Xe 131.29
						` ′											
Cs ⁵⁵	Ba 56	57–71	Hf ⁷²	73 Ta	\mathbf{W}^{74}	Re 75	Os 76	1r 77	Pt 78	79 Au	\mathbf{Hg}^{80}	\mathbf{Tl}^{81}	Pb 82	Bi 83	Po 84	At 85	Rn 86
132.91	137.33	Lanthanoids	178.49	180.95	183.84	186.21	190.23	192.22	195.08	196.97	200.59	204.38	207.2	208.98	(210.0)	(210.0)	(222.0)
87	88	89–103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
Fr	Ra	Actinoids	Rf	Db	$\mathbf{S}\mathbf{g}^{100}$	\mathbf{Bh}^{107}	Hs	Mt	$\mathbf{D}_{\mathbf{S}}^{110}$	Rg	Cn	Nh	Fl	Mc	$\mathbf{L}_{\mathbf{v}}^{\mathbf{n}_{0}}$	Ts	Og
(223.0)	(226.1)	Actinoids	(261.1)	(262.1)	(263.1)	(264.1)	(265.1)	(268)	(281)	(272)	(285)	(284)	(289)	(288)	(293)	(294)	(294)
		'															
			57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
		$\downarrow \downarrow \rightarrow$	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	$\mathbf{D}\mathbf{y}$	Ho	Er	Tm	Yb	Lu
			138.91	140.12	140.91	144.24	(146.9)	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.05	174.97
			89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
		\longrightarrow	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
			(227.0)	232.0	231.0	238.0	(237.0)	(239.1)	(241.1)	(244.1)	(249.1)	(252.1)	(252.1)	(252.1)	(258.1)	(259.1)	(262.1)

Groups are numbered according to IUPAC convention 1–18.

^{*}Values in brackets are for the isotope with the longest half-life.