Neap

Trial Examination 2020

Question and response booklet

QCE Physics Units 3&4

Paper 2

Student's Name: _____

Teacher's Name: _____

Time allowed
- Perusal time – 10 minutes
- Working time – 90 minutes

General instructions
- Answer all questions in this question and response booklet.
- Write using black or blue pen.
- Respond in full paragraphs consisting of full sentences.
- QCAA-approved calculator permitted.
- QCAA formula sheet provided.
- Planning paper will not be marked.

Section 1 (45 marks)
- 8 short response questions

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2020 QCE Physics Units 3&4 examination.

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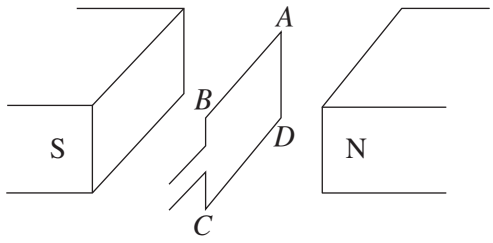
SECTION 1

Instructions

- If you need more space for a response, use the additional pages at the back of this booklet.
  - On the additional pages, write the question number you are responding to.
  - Cancel any incorrect response by ruling a single diagonal line through your work.
  - Write the page number of your alternative/additional response, i.e. See page …
  - If you do not do this, your original response will be marked.

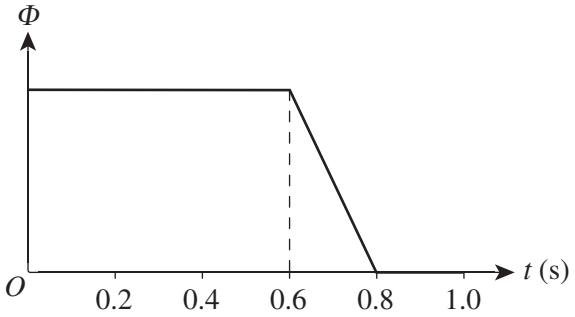
QUESTION 1 (8 marks)

Two Physics students investigate electromagnetic induction using the equipment shown below. The magnet provides a uniform magnetic field of 0.8 T. The sides of the square coil are 5.0 cm in length. The voltage across the ends of the coil is measured using a cathode ray oscilloscope (CRO).

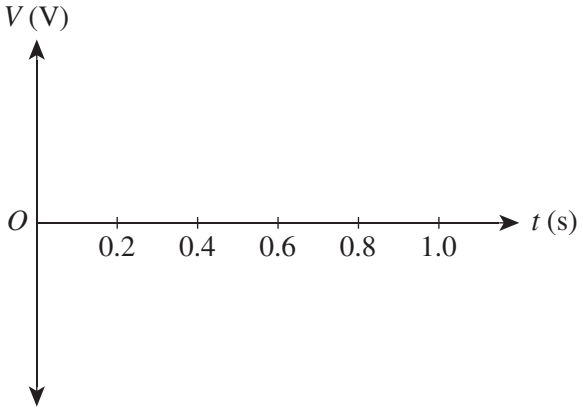


The student moves the coil vertically upwards and out of the field at a constant speed. The entire coil is within the field from $t = 0.0$ s until $t = 0.6$ s. It leaves the field between $t = 0.6$ s and $t = 0.8$ s.

a) The graph below shows how the magnetic flux though the coil varies with time.



On the axes below, sketch a graph to show the variation with time of the voltage across the ends of the coil. Do not include values on the *y*-axis. *[2 marks]*



b) Calculate the magnitude of the average emf as the coil is moved vertically and out of the field. Show your working. *[2 marks]*

emf =_____ V (to 2 decimal places)

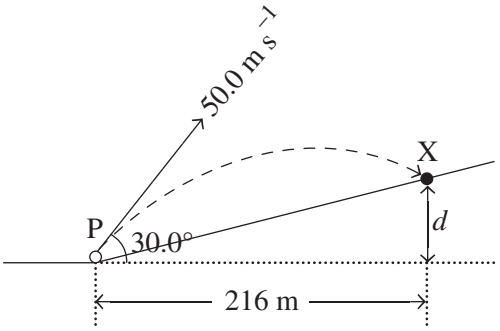
c) The coil is pulled up and out of the magnetic field, and the induced current flows.

In which direction, *A* to *B* or *B* to *A*, does the induced current flow? Explain your answer. *[3 marks]*

d) Without changing the size or magnitude of the equipment, state one way that the induced emf can be increased. *[1 mark]*

QUESTION 2 (8 marks)

A golfer hits a golf ball at point P as shown on the diagram below, which is on a fairway that is sloping upwards away from the golfer. The golfer hits the ball at a speed of 50.0 m s^{-1} and at an angle of 30.0° to the horizontal. The ball lands at point X, a horizontal launch plane 216 m away from point P. Point X is a distance (d) vertically above the launch plane. Air resistance is negligible.



a) Calculate the time taken by the golf ball to reach point X. Show your working. *[2 marks]*

Time taken =_____ s (to 2 decimal places)

b) Calculate the vertical distance (d) between point P and X. Show your working. *[2 marks]*

Vertical drop (d) =_____ m (to 1 decimal place)

c) Calculate the velocity of the ball as it hits the ground at point X and the angle at which it hits the ground, as measured from the horizontal. Show your working. *[4 marks]*

Velocity =_____ m s^{-1} (to 1 decimal place)

Angle =_____ ° (to 1 decimal place)

QUESTION 3 (9 marks)

Muons are elementary particles that are produced above the ground when cosmic radiation from outer space collides with the atoms of the Earth's atmosphere. Experiments have found laboratory muons to be unstable. They decay with a half-life (the time for half of a large number of muons to decay) of 2.2 μs when measured at rest in their frame of reference.

In a particular experiment, a detector recorded muons travelling at 0.995c at an altitude of 1.200 km above the Earth's surface.

a) Show that the Lorenz factor in this experiment is equal to 10.01. *[2 marks]*

b) Calculate the half-life of the moving muons, as measured from the ground. *[2 marks]*

Half-life =_____ μs (to the nearest whole number)

c) At what height above ground is the muon created, as measured by a muon in its reference frame? *[2 marks]*

Height =_____ km (to 2 decimal places)

d) Muons have a mass energy of 105.66 MeV.

Calculate the kinetic energy of a muon travelling at $0.995c$. *[3 marks]*

_____

_____

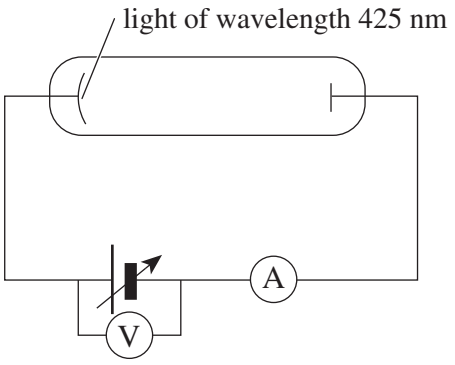
_____

_____

Kinetic energy =_____ MeV (to 2 decimal places)

QUESTION 4 (4 marks)

Light of wavelength $\lambda = 425$ nm strikes a clean metallic surface and photoelectrons are emitted. A stopping voltage (V_S) of 1.25 V is required to reduce the current (I) to zero in the circuit shown below.



a) Calculate the magnitude of the maximum velocity of a photoelectron. *[2 marks]*

_____

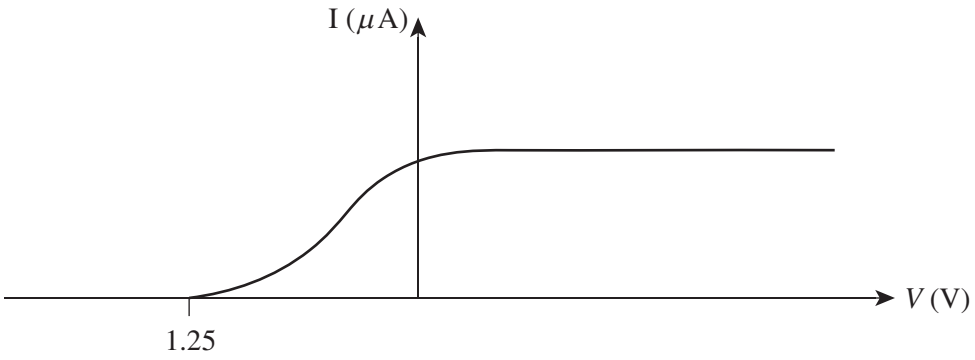
_____

_____

_____

Maximum velocity = _____ m s^{-1} (to 1 decimal place)

b) The graph below shows the current versus stopping voltage characteristic curve for the metal surface.



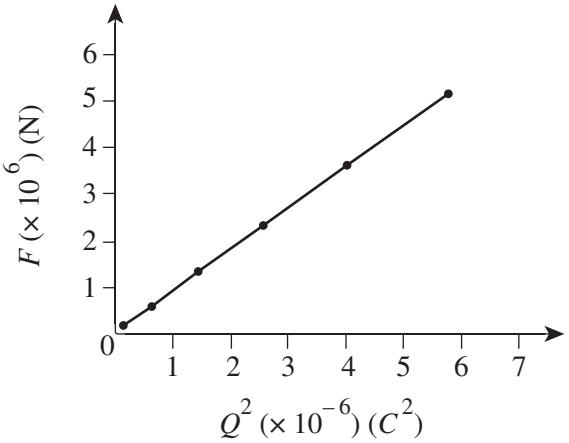
On the graph above, sketch the curve produced when a light of higher frequency and lower intensity is shone on the metal surface. *[2 marks]*

QUESTION 5 (4 marks)

James and Ava carry out an electrostatics experiment to investigate the forces between six different pairs of equally charged spheres. The charges were placed at a fixed distance apart. The table below shows the data James and Ava collected.

Charge on single sphere, Q (C) ($\times 10^{-4}$)	**Product of charge on both spheres, Q^2 (C^2) ($\times 10^{-6}$)**	**Force between charges (N), ($\times 10^{6}$)**
4.00	0.16	0.14
8.00	0.64	0.58
12.00	1.44	1.30
16.00	2.56	2.30
20.00	4.00	3.60
24.00	5.76	5.18

They used these results to produce the force versus charge-squared graph below.



Use the gradient to calculate the distance between the spheres (r). Show your working.

r = _____ m (to 1 decimal place)

QUESTION 6 (5 marks)

The ionic radius (outer shell) of strontium is 255 pm.

a) What is the ionic radius of strontium in metres? *[1 mark]*

Ionic radius of strontium =_____m (to 2 decimal places)

b) Determine the longest wavelength of an electron at this radius. *[2 marks]*

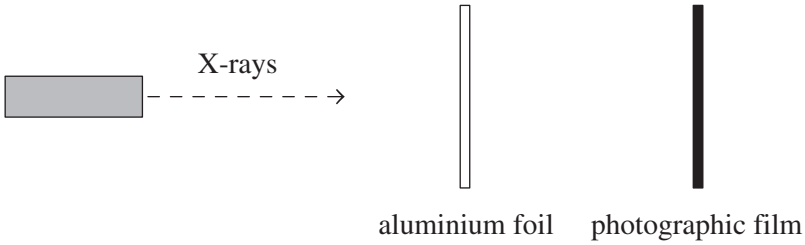
λ = _____ m (to 2 decimal places)

c) Calculate the speed of an electron at the longest wavelength at this radius. *[2 marks]*

Speed of electron =_____ m s^{-1} (to 2 decimal places)

QUESTION 7 (2 marks)

The diagram below shows a beam of X-rays with wavelength $\lambda = 200$ pm (200×10^{-12} m) directed at a thin sheet of aluminium foil. The X-rays scatter from the aluminium foil onto a photographic film.



Calculate the energy of the X-rays.

Energy = _____ J (to 2 decimal places)

QUESTION 8 (5 marks)

a) Define the term *black-body radiation*. *[1 mark]*

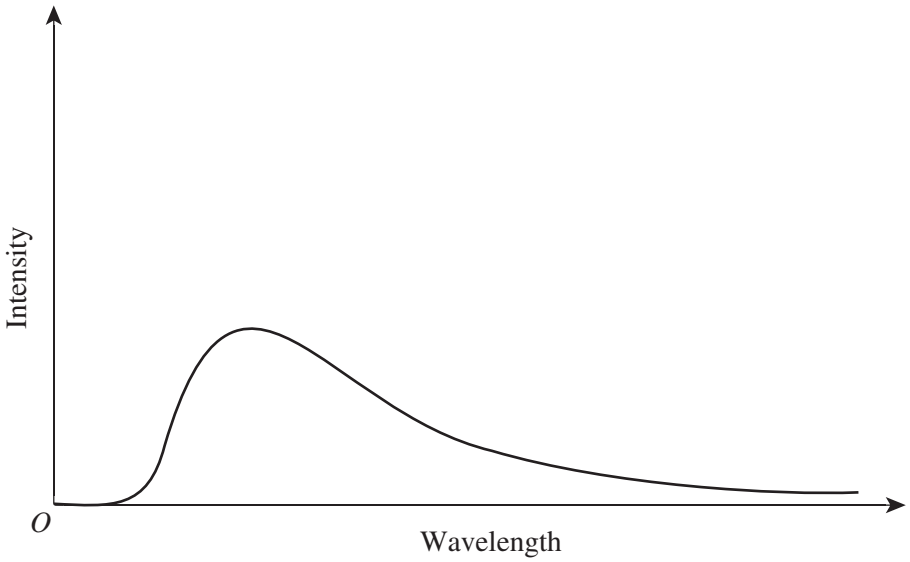
_____

_____

_____

_____

b) The graph of intensity versus wavelength for the black-body radiation spectrum of a certain star is shown below.



On the graph above, sketch the black-body radiation spectrum of a star with a higher surface temperature than the star shown. *[2 marks]*

c) The star Betelgeuse is usually the tenth-brightest star in the night sky. It emits black-body radiation that has a maximum intensity at a wavelength of 970 nm.

Calculate the surface temperature of Betelgeuse. *[2 marks]*

_____

_____

_____

_____

Surface temperature =_____K (to the nearest whole number)

END OF PAPER

ADDITIONAL PAGE FOR STUDENT RESPONSES

Write the question number you are responding to.

ADDITIONAL PAGE FOR STUDENT RESPONSES

Write the question number you are responding to.

Neap

Trial Examination 2020

Formula and data booklet

QCE Physics Units 3&4

FORMULAS

Processing of data
Percentage uncertainty (%) = $\dfrac{\text{absolute uncertainty}}{\text{measurement}} \times 100$
Percentage error (%) = $\left\lvert\dfrac{\text{measured value} - \text{true value}}{\text{true value}}\right\rvert \times 100$

Heating processes	
$T_K = T_C + 273$	$Q = mL$
$Q = mc\Delta T$	$\Delta U = Q + W$
$\eta = \dfrac{\text{energy output}}{\text{energy input}} \times \dfrac{100}{1}\%$	

Ionising radiation and nuclear reactions	
$N = N_0\left(\dfrac{1}{2}\right)^n$	$\Delta E = \Delta mc^2$

Electrical circuits	
$I = \dfrac{q}{t}$	$P = I^2R$
$V = \dfrac{W}{q}$	$V_t = V_1 + V_2 + \ldots V_n$
$P = \dfrac{W}{t}$	$R_t = R_1 + R_2 + \ldots R_n$
$R = \dfrac{V}{I}$	$I_t = I_1 + I_2 + \ldots I_n$
$P = VI$	$\dfrac{1}{R_t} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots \dfrac{1}{R_n}$

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

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

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

Special relativity	
$t = \frac{t_0}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$	$p_v = \frac{m_0 v}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$
$L = L_0\sqrt{\left(1-\frac{v^2}{c^2}\right)}$	$\Delta E = \Delta mc^2$

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

PHYSICAL CONSTANTS AND UNIT CONVERSIONS

Heating processes	
Latent heat of fusion for water	$L_f = 3.34 \times 10^5$ J kg^{-1}
Latent heat of vaporisation for water	$L_v = 2.26 \times 10^6$ J kg^{-1}
Specific heat capacity of ice	$c_i = 2.05 \times 10^3$ J kg^{-1} K^{-1}
Specific heat capacity of steam	$c_s = 2.00 \times 10^3$ J kg^{-1} K^{-1}
Specific heat capacity of water	$c_w = 4.18 \times 10^3$ J kg^{-1} K^{-1}

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

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

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

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

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

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

Quantum theory	
Wien's displacement constant	$b = 2.898 \times 10^{-3} \text{ m K}$
Planck's constant	$h = 6.626 \times 10^{-34} \text{ J s}$
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
10^{9}	giga	G
10^{12}	tera	T

LIST OF ELEMENTS BY NAME

Name	Atomic no.	Symbol
Hydrogen	1	H
Helium	2	He
Lithium	3	Li
Beryllium	4	Be
Boron	5	B
Carbon	6	C
Nitrogen	7	N
Oxygen	8	O
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	Co
Nickel	28	Ni
Copper	29	Cu
Zinc	30	Zn
Gallium	31	Ga
Germanium	32	Ge
Arsenic	33	As
Selenium	34	Se
Bromine	35	Br

Name	Atomic no.	Symbol
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
Tellerium	52	Te
Iodine	53	I
Xenon	54	Xe
Cesium	55	Cs
Barium	56	Ba
Lanthanum	57	La
Cerium	58	Ce
Praseodymium	59	Pr
Neodymium	60	Nd
Promethium	61	Pm
Samarium	62	Sm
Europium	63	Eu
Gadolinium	64	Gd
Terbium	65	Tb
Dysprosium	66	Dy
Holmium	67	Ho
Erbium	68	Er
Thulium	69	Tm
Ytterbium	70	Yb

LIST OF ELEMENTS BY NAME (continued)

Name	Atomic no.	Symbol
Lutetium	71	Lu
Hafnium	72	Hf
Tantalum	73	Ta
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
Protactinium	91	Pa
Uranium	92	U
Neptunium	93	Np
Plutonium	94	Pu

Name	Atomic no.	Symbol
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
Copernicum	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

KEY

1	atomic number
H	symbol
1.01	relative atomic mass*

1																	18
1 H 1.01	2											13	14	15	16	17	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3	4	5	6	7	8	9	10	11	12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc (98.91)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57–71 Lathanoids	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (210.0)	85 At (210.0)	86 Rn (222.0)
87 Fr (223.0)	88 Ra (226.1)	89–103 Actinoids	104 Rf (261.1)	105 Db (262.1)	106 Sg (263.1)	107 Bh (264.1)	108 Hs (265.1)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)	113 Nh (284)	114 Fl (289)	115 Mc (288)	116 Lv (293)	117 Ts (294)	118 Og (294)

Lathanoids														
57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (146.9)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97

Actinoids														
89 Ac (227.0)	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237.0)	94 Pu (239.1)	95 Am (241.1)	96 Cm (244.1)	97 Bk (249.1)	98 Cf (252.1)	99 Es (252.1)	100 Fm (252.1)	101 Md (258.1)	102 No (259.1)	103 Lr (262.1)

Groups are numbered according to IUPAC convention 1–18.
*Values in brackets are for the isotope with the longest half-life.