NSW Education Standards Authority

2019 **HIGHER SCHOOL CERTIFICATE EXAMINATION**

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A data sheet, formulae sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks (pages 2–14)

- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – 80 marks (pages 17–36)

- Attempt Questions 21–36
- Allow about 2 hours and 25 minutes for this section

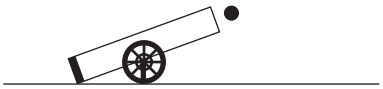
Section I

20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1–20.

---

1 A projectile is launched by a cannon as shown.



Which arrow represents the velocity of the projectile at its maximum height?

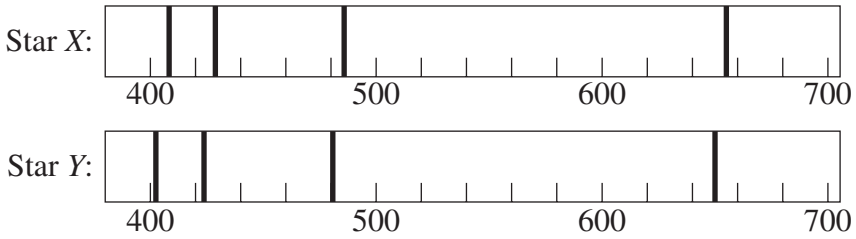
A. ↑

B. ↓

C. ↘

D. →

2 Two stars were observed from Earth. Their spectra are shown with the wavelength in nanometres.



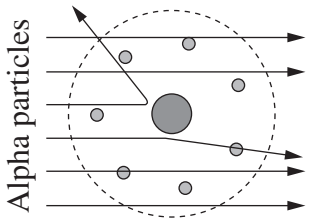
Using these spectra, what can be concluded about the motion of the stars relative to Earth and their chemical compositions?

	Motion relative to Earth	*Chemical composition*
A.	The same	The same
B.	Different	The same
C.	The same	Different
D.	Different	Different

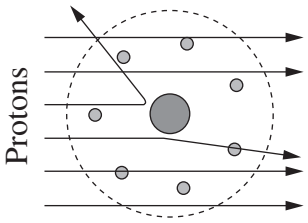
3 Geiger and Marsden carried out an experiment to investigate the structure of the atom.

Which diagram identifies the particles they used and the result that they INITIALLY expected?

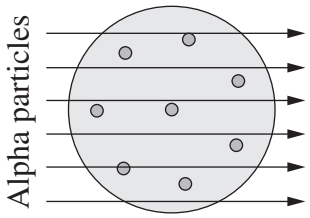
A.



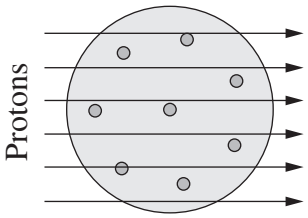
B.



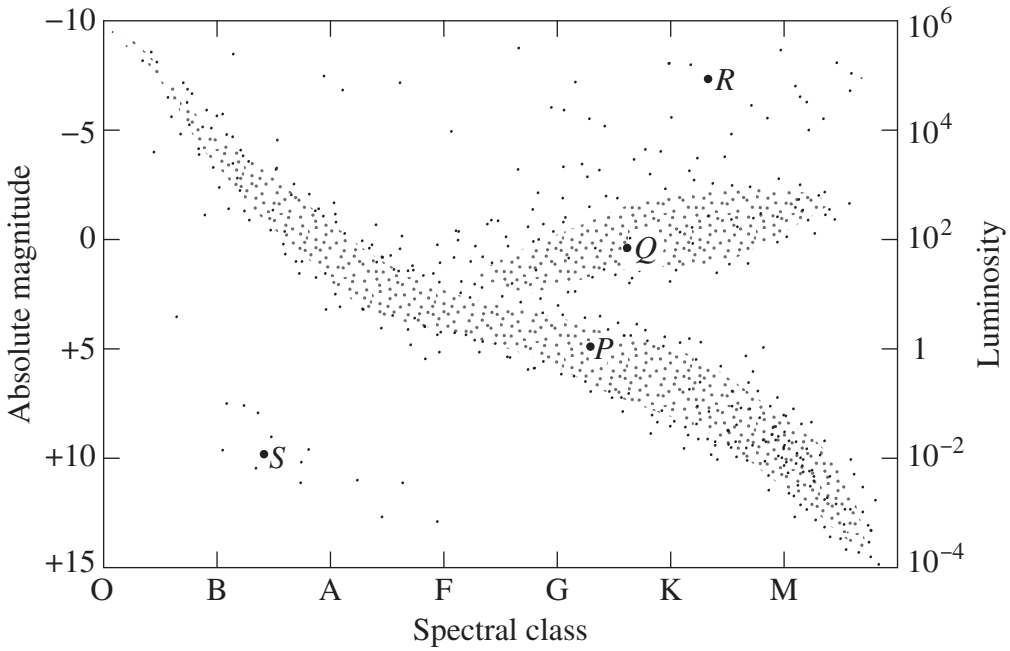
C.



D.



4 Four stars, *P*, *Q*, *R* and *S*, are labelled on the Hertzsprung–Russell diagram.



Which statement is correct?

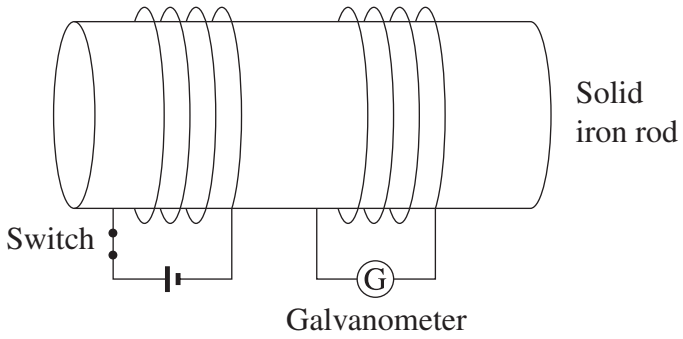
A. *S* has a greater luminosity than *Q*.

B. *R* is a blue star whereas *S* is a red star.

C. *S* has a higher surface temperature than *R*.

D. *P* is at a more advanced stage of its evolution than *R*.

5 The diagram shows two coils wound around a solid iron rod. Initially the switch is closed.



Opening the switch will cause the galvanometer pointer to

A. remain at a constant reading.

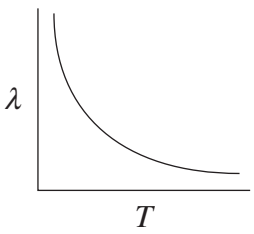
B. move from a non-zero reading to a zero reading.

C. move from a zero reading to a non-zero reading, where it remains.

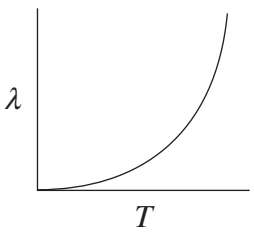
D. move from a zero reading to a non-zero reading, then back to zero.

6 Which graph correctly shows the relationship between the surface temperature of a black body (T) and the wavelength (λ) at which the maximum intensity of light is emitted?

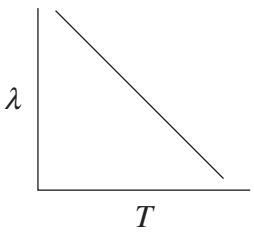
A.



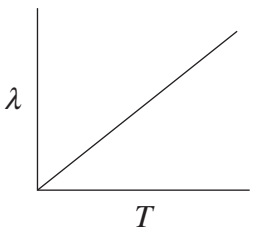
B.



C.



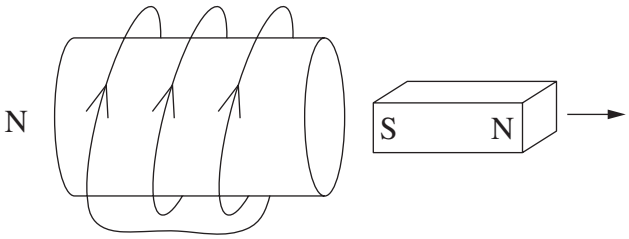
D.



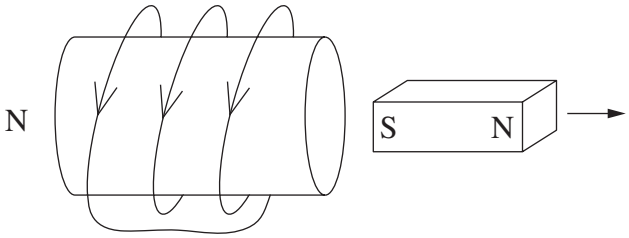
7 A bar magnet is moved away from a stationary coil.

Which diagram correctly shows the direction of the induced current in the coil and the resulting magnetic polarity of the coil?

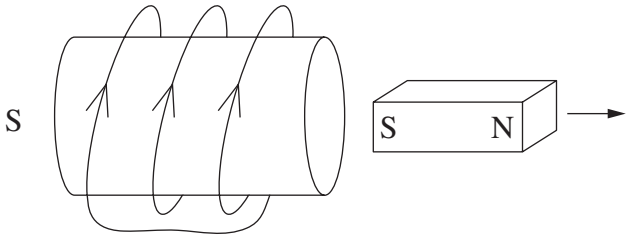
A.



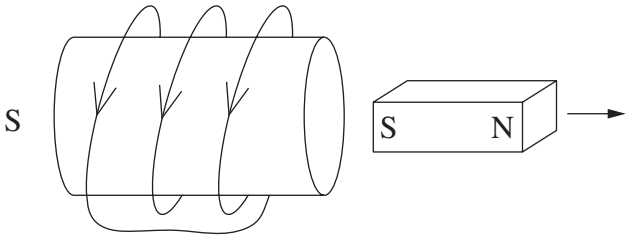
B.



C.



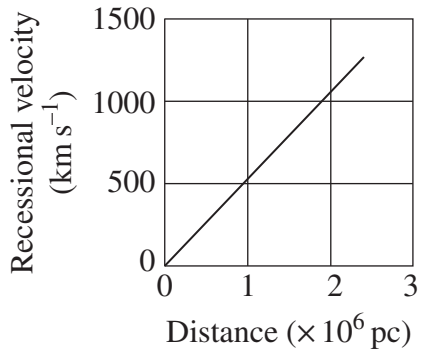
D.



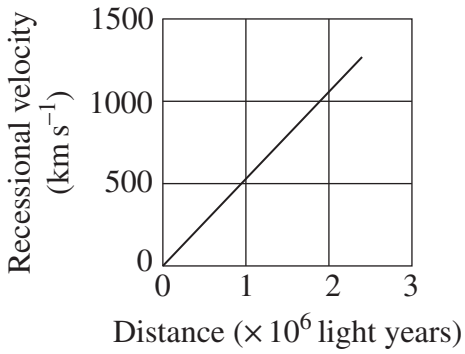
8 A typical galaxy has a diameter of 100 000 light years (~30 000 pc).

Which graph is consistent with Hubble's measurements of the recessional velocity of galaxies?

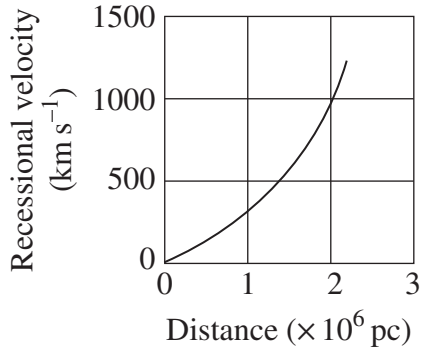
A.



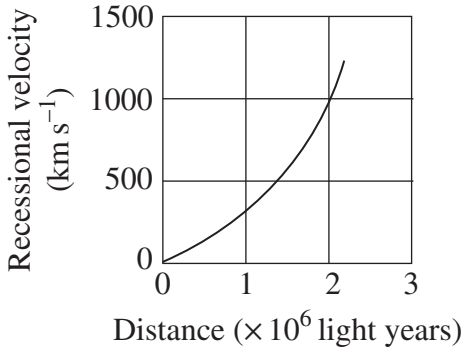
B.



C.



D.



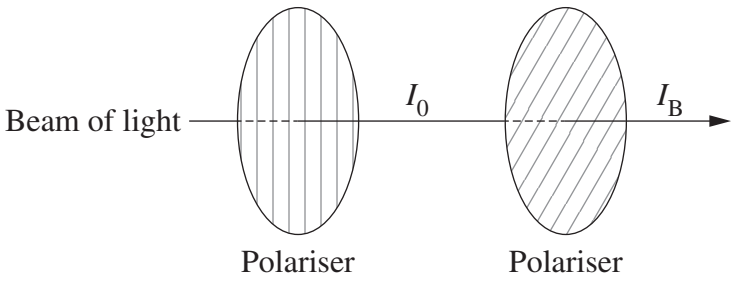
9 Two satellites have the same mass. One (LEO) is in low-Earth orbit and the other (GEO) is in a geostationary orbit.

The total energy of a satellite is half its gravitational potential energy.

Which row of the table correctly identifies the satellite with the greater orbital period and the satellite with the greater total energy?

	Greater orbital period	*Greater total energy*
A.	LEO	LEO
B.	LEO	GEO
C.	GEO	LEO
D.	GEO	GEO

10 A beam of light passes through two polarisers. The second polariser has a transmission axis at an angle of 30° to that of the first polariser. The intensity of the light beam before and after the second polariser is I_0 and I_B respectively.



Which row of the table correctly identifies the value of $\frac{I_B}{I_0}$, and the model of light demonstrated by this investigation?

	Value of $\frac{I_B}{I_0}$	*Model of light demonstrated*
A.	0.750	Wave model
B.	0.750	Particle model
C.	0.866	Wave model
D.	0.866	Particle model

11 A dwarf planet orbits the sun with a period of 40 000 years.

The average distance from the sun to Earth is one astronomical unit.

What is the average distance between this dwarf planet and the sun in astronomical units?

A. 34

B. 200

C. 1170

D. 8×10^6

12 The table shows two types of quarks and their respective charges.

Quark	*Symbol*	*Charge*
Up	*u*	$+\frac{2}{3}$
Down	*d*	$-\frac{1}{3}$

In a particular nuclear transformation, a particle having a quark composition *udd* is transformed into a particle having a quark composition *uud*.

What is another product of this transformation?

A. Electron

B. Neutron

C. Positron

D. Proton

13 A laser has a power output of 30 mW and emits light with a wavelength of 650 nm.

How many photons does this laser emit per second?

A. 4.6×10^{14}

B. 9.8×10^{16}

C. 3.1×10^{19}

D. 9.3×10^{21}

14 A satellite in circular orbit at a distance r from the centre of Earth has an orbital velocity v.

If the distance was increased to $2r$, what would be the satellite's orbital velocity?

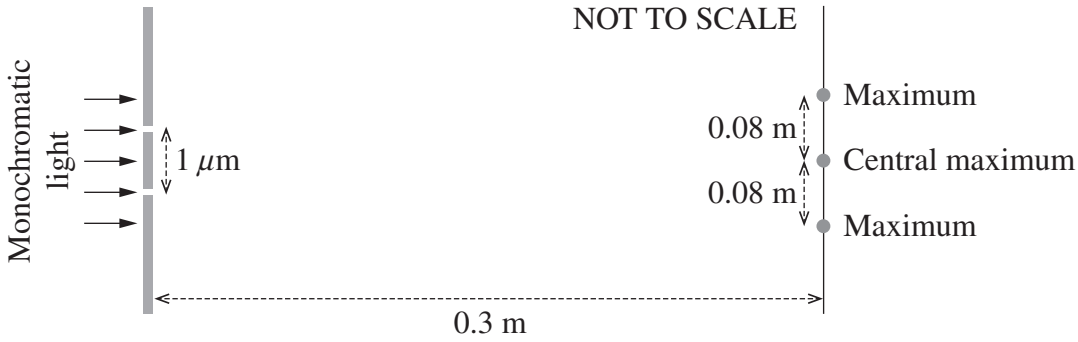
A. $\frac{v}{2}$

B. $0.7v$

C. $1.4v$

D. $2v$

15 Monochromatic light passes through two slits $1\ \mu$m apart. The resulting diffraction pattern is measured at a distance of 0.3 m.

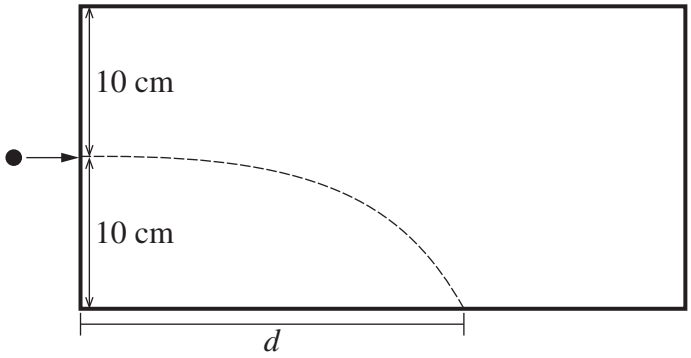


This diffraction pattern can be analysed using the equation $d \sin\theta = \lambda$.

What values of d and θ should be used in the equation?

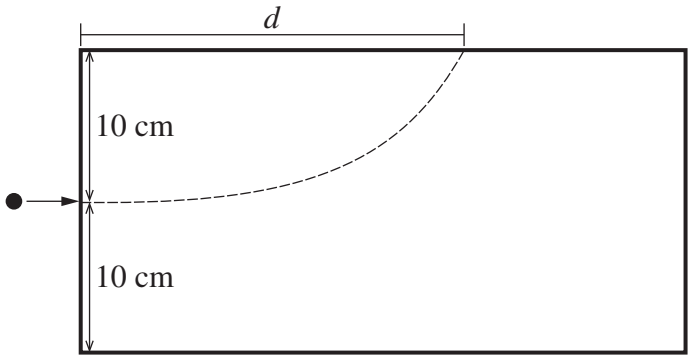
	d	θ
A.	0.3 m	$\tan^{-1}\left(\frac{0.08}{0.3}\right)$
B.	0.3 m	$\sin^{-1}\left(\frac{0.08}{0.3}\right)$
C.	$1\ \mu$m	$\tan^{-1}\left(\frac{0.08}{0.3}\right)$
D.	$1\ \mu$m	$\sin^{-1}\left(\frac{0.08}{0.3}\right)$

16 The diagram shows the trajectory of a particle with charge q and mass m when fired horizontally into a vacuum chamber, where it falls under the influence of gravity.



The horizontal distance, d, travelled by the particle is recorded.

The experiment is repeated with a uniform vertical electric field applied such that the particle travels the same horizontal distance, d, but strikes the upper surface of the chamber.



What is the magnitude of the electric field?

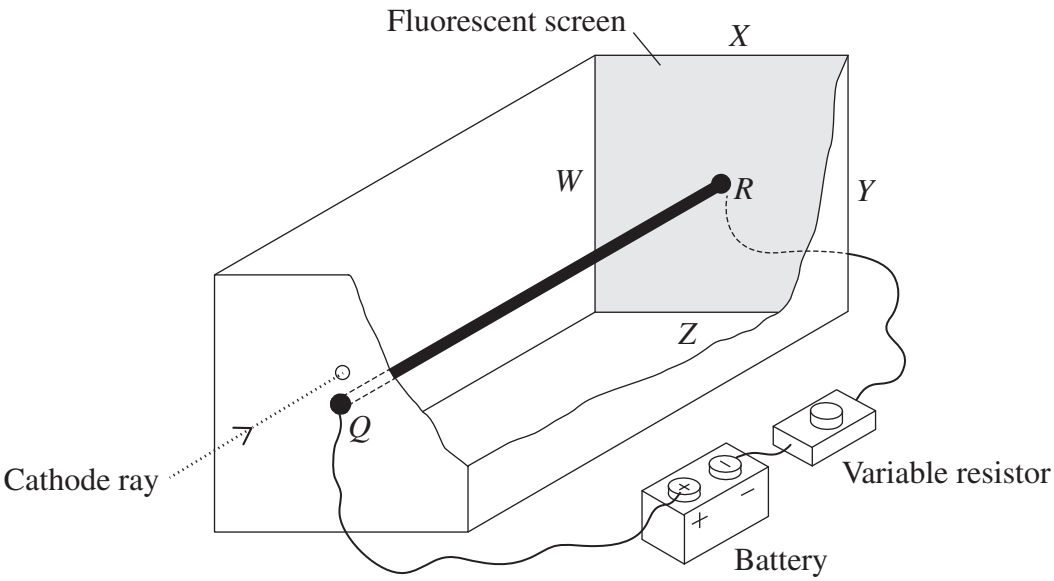
A. mgq

B. $2mgq$

C. $\dfrac{mg}{q}$

D. $\dfrac{2mg}{q}$

17 A straight current-carrying conductor, *QR,* is connected to a battery and a variable resistor. *QR* is enclosed in an evacuated chamber with a fluorescent screen at one end.



A cathode ray enters the chamber directly above *Q*, initially travelling parallel to *QR*. It passes through the chamber and strikes the fluorescent screen causing a bright spot.

Which direction will this spot move towards if the resistance is increased?

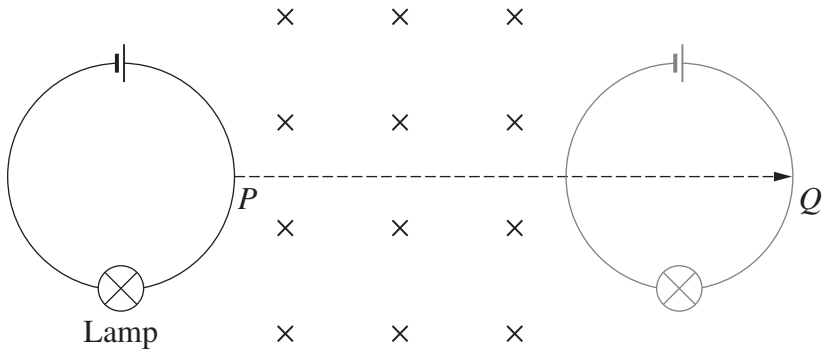
A. *W*

B. *X*

C. *Y*

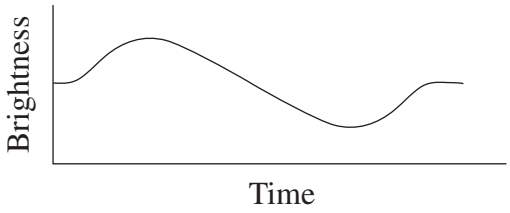
D. *Z*

18 A circular loop of wire is connected to a battery and a lamp. The apparatus is moved from *P* to *Q* along the path shown at a constant velocity through a region containing a uniform magnetic field.

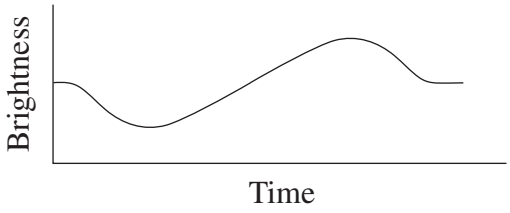


Which graph shows the brightness of the lamp as the apparatus moves between *P* and *Q*?

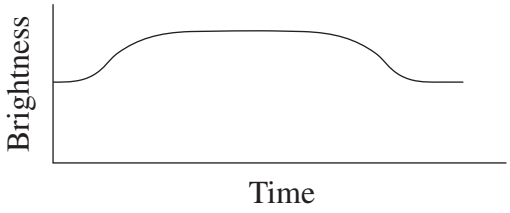
A.



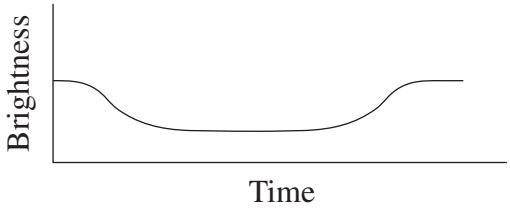
B.



C.



D.



19 Consider the following nuclear reaction.

$$W + X \rightarrow Y + Z$$

Information about W, X and Y is given in the table.

Species	*Mass defect* (*u*)	*Total binding energy* (MeV)	*Binding energy per nucleon* (MeV)
W	0.00238817	2.224566	1.112283
X	0.00910558	8.481798	2.827266
Y	0.03037664	28.29566	7.073915

Which of the following is a correct statement about energy in this reaction?

A. The reaction gives out energy because the mass defect of Y is greater than that of either W or X.

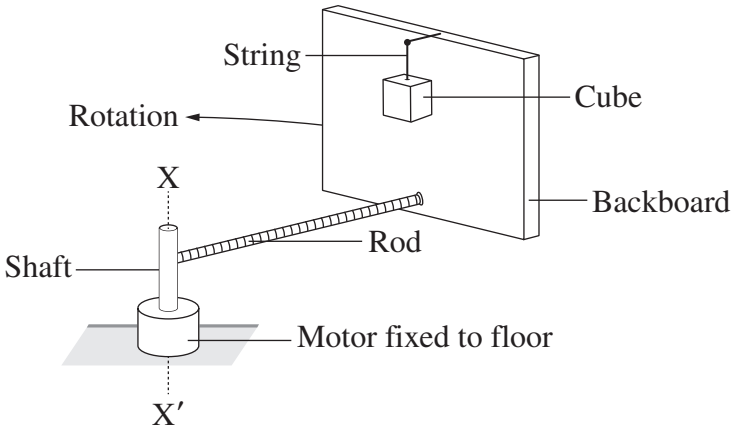
B. It cannot be deduced whether the reaction releases energy because the properties of Z are not known.

C. The reaction requires an input of energy because the mass defect of the products is greater than the sum of the mass defects of the reactants.

D. Energy is released by the reaction because the binding energy of the products is greater than the sum of the binding energies of the reactants.

20 In the apparatus shown, a backboard is connected by a rod to a shaft. The shaft is spun by an electric motor causing the backboard to rotate in the horizontal plane around the axis X–X′.

A cube is suspended by a string so that it touches the surface of the backboard.



When the angular velocity of the motor is great enough, the string is cut and the position of the cube does not change relative to the backboard.

Which statement correctly describes the forces after the string is cut?

A. The sum of the forces on the cube is zero.

B. The horizontal force of the backboard on the cube is equal in magnitude to the horizontal force of the cube on the backboard.

C. The horizontal force of the backboard on the cube is greater than the horizontal force of the cube on the backboard, resulting in a net centripetal force.

D. The force of friction between the cube and the backboard is independent of the force of the backboard on the cube because these forces are perpendicular to each other.

BLANK PAGE

BLANK PAGE

2019 HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Student Number

Physics

Section II Answer Booklet

80 marks
Attempt Questions 21–36
Allow about 2 hours and 25 minutes for this section

Instructions

- Write your Centre Number and Student Number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (2 marks)

Outline de Broglie's contribution to quantum mechanics. Support your answer with a relevant equation. **2**

.....

.....

.....

.....

Question 22 (3 marks)

Spectra can be used to determine the chemical composition and surface temperature of stars. **3**

Describe how spectra provide information about OTHER features of stars.

.....

.....

.....

.....

.....

.....

.....

.....

Do NOT write in this area.

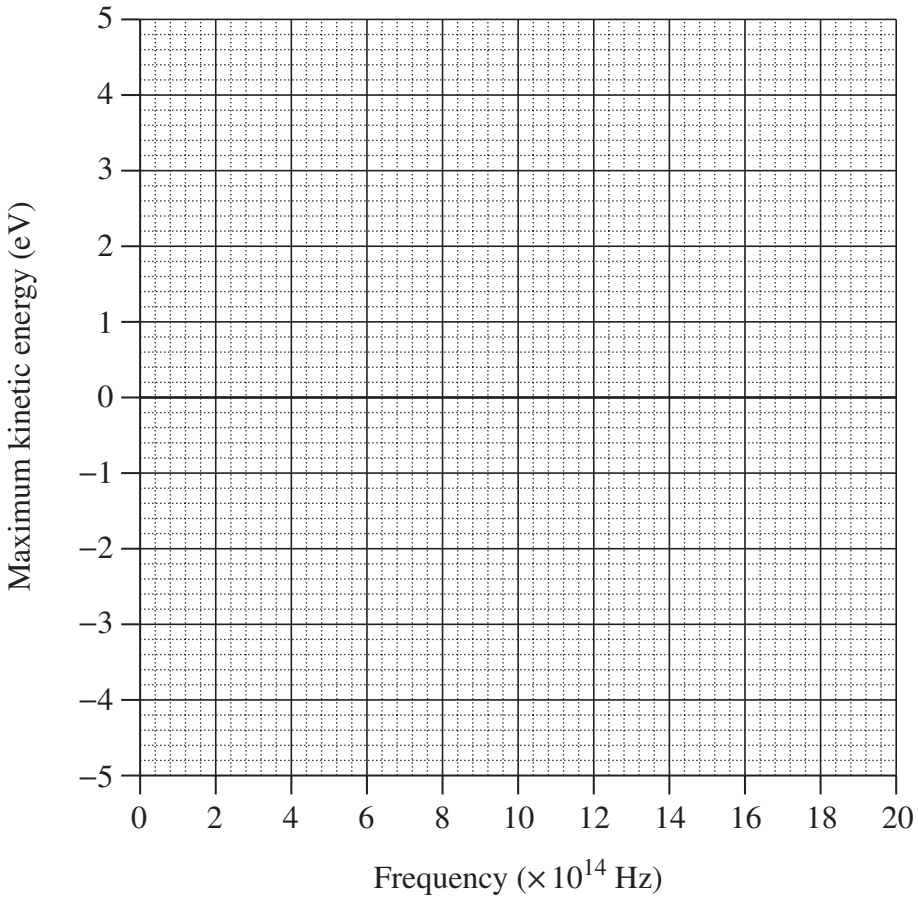
Question 23 (3 marks)

A student investigated the photoelectric effect. The frequency of light incident on a metal surface was varied and the corresponding maximum kinetic energy of the photoelectrons was measured. **3**

The following results were obtained.

Frequency ($\times 10^{14}$ Hz)	11.2	13.5	15.2	18.6	20.0
Maximum kinetic energy (eV)	0.6	1.3	2.3	3.3	4.2

Plot the results on the axes below and hence determine the work function of the metal in electron volts.



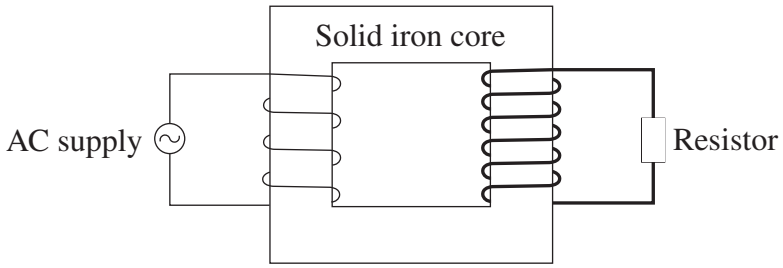
.....

.....

.....

Question 24 (7 marks)

A step-up transformer is constructed using a solid iron core. The coils are made using copper wires of different thicknesses as shown.



The table shows electrical data for this transformer.

V_s	I_s	$V_p I_p$
50 V	9 A	500 J s^{-1}

(a) Explain how the operation of this transformer remains consistent with the law of conservation of energy. Include a relevant calculation in your answer. **3**

.....

.....

.....

.....

.....

.....

(b) Explain how TWO modifications to this transformer would improve its efficiency. **4**

.....

.....

.....

.....

.....

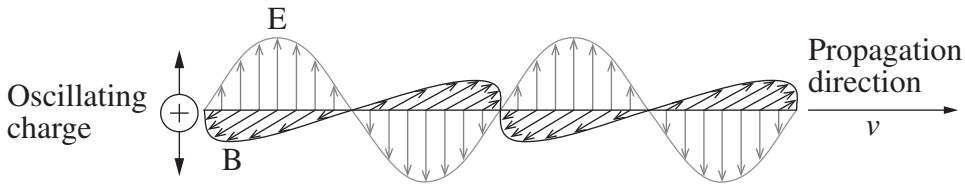
.....

.....

.....

Question 25 (4 marks)

The diagram shows a model of electromagnetic waves. **4**



Relate this model to predictions made by Maxwell.

.....

.....

.....

.....

.....

.....

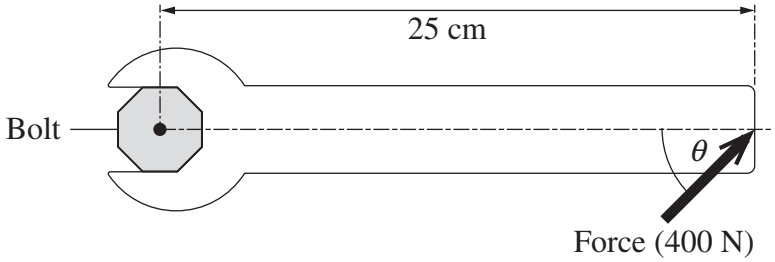
.....

.....

Please turn over

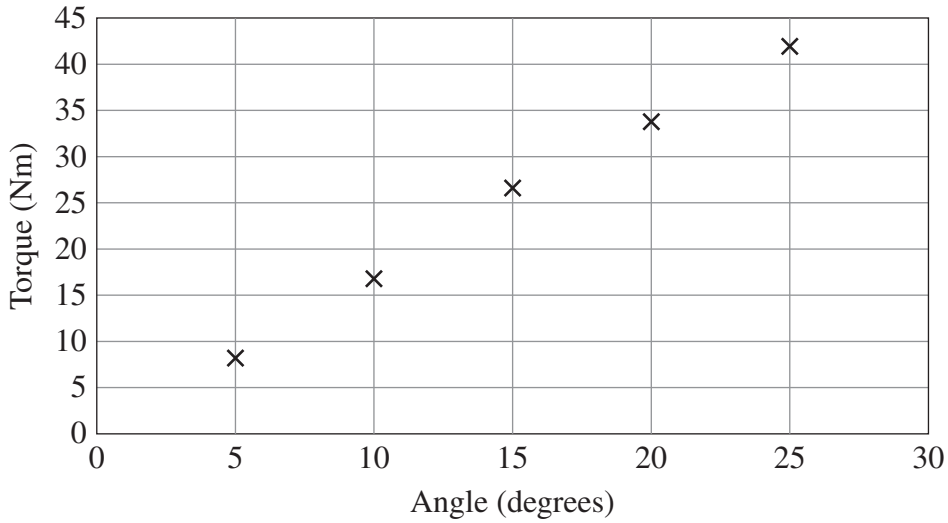
Question 26 (6 marks)

A student carried out an experiment to investigate the relationship between the torque produced by a force and the angle at which the force is applied. A 400 N force was applied to the same position on the handle of a spanner at different angles, as shown.



A high-precision device measured the torque applied to the bolt.

The data from the experiment is graphed below.



Question 26 continues on page 23

Question 26 (continued)

The student concluded that the torque (τ) was proportional to the angle (θ) and proposed the model

$$\tau = k\theta$$

where $k = 1.7$ Nm/degree.

(a) Justify the validity of the student's model using information from the graph. **3**

.....

.....

.....

.....

.....

.....

(b) What happens to the accuracy of this model's predictions as the angle increases beyond 25°? Justify your answer with reference to a different model. **3**

.....

.....

.....

.....

.....

.....

End of Question 26

Question 27 (6 marks)

(a) Outline a thought experiment that relates to the prediction of time dilation. **3**

.....

.....

.....

.....

.....

.....

(b) Outline experimental evidence that validated the prediction of time dilation. **3**

.....

.....

.....

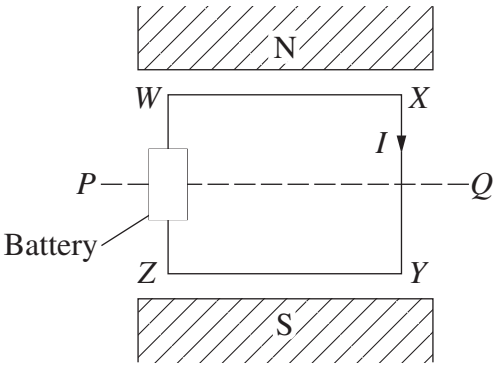
.....

.....

.....

Question 28 (3 marks)

A metal loop, *WXYZ* is connected to a battery and placed in a uniform magnetic field. A current flows through the loop in the direction shown. **3**



The loop is then allowed to rotate by 90° about the axis *PQ*.

Compare the forces acting on *WX* and *XY* before and after this rotation.

.....

.....

.....

.....

.....

.....

Do NOT write in this area.

Question 29 (3 marks)

A particle having mass m and charge q is accelerated from rest through a potential difference V. Assume that the only force acting on the particle is due to the electric field associated with this potential difference. **3**

Show that the final velocity of the particle is given by $v = \sqrt{\frac{2qV}{m}}$.

.....

.....

.....

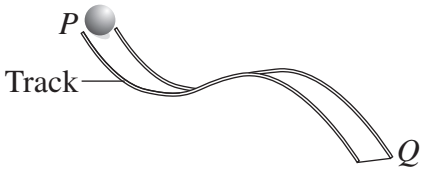
.....

.....

Do NOT write in this area.

Question 30 (6 marks)

A ball, initially at rest in position P, travels along a frictionless track to point Q and then falls to strike the floor below.



NOT TO SCALE

At the instant the ball leaves the track at Q it has a velocity of 1.5 m s^{-1} at an angle of 50° to the horizontal.

(a) Calculate the difference in height between P and Q. **3**

.....

.....

.....

.....

.....

.....

(b) The ball takes 0.5 s to reach the floor after leaving the track at Q. **3**

Calculate the height of Q above the floor.

.....

.....

.....

.....

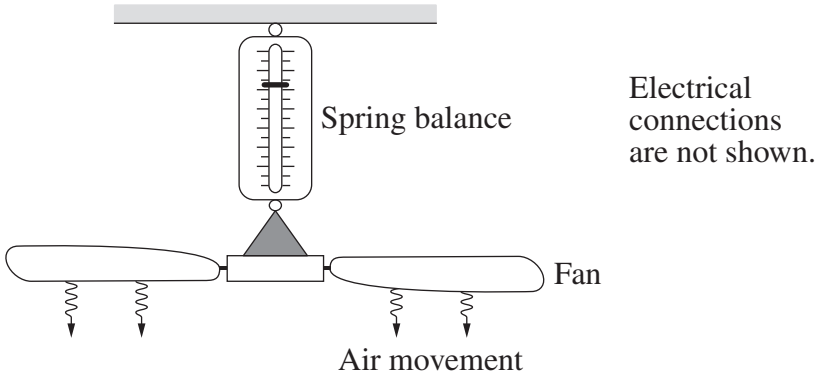
.....

.....

Question 31 (8 marks)

A student suspends an electric ceiling fan from a spring balance.

The fan is switched on, reaching a maximum rotational velocity after ten seconds.



(a) Explain the changes that would be observed on the spring balance in the first 15 seconds after the fan is switched on. **4**

.....

.....

.....

.....

.....

.....

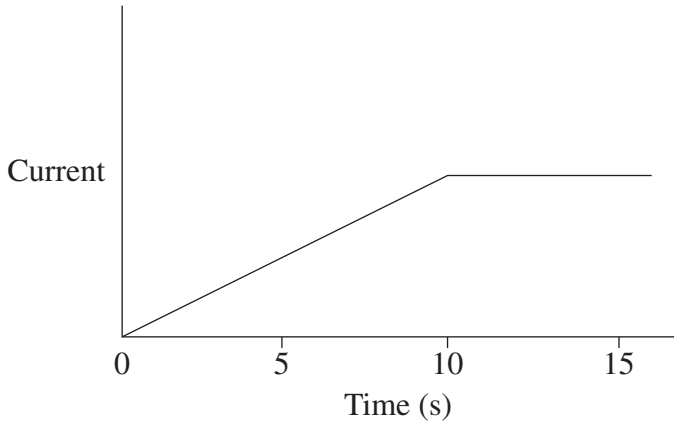
.....

.....

Question 31 continues on page 29

Question 31 (continued)

(b) The student predicted that the current through the fan's motor would vary as shown on the graph. **4**



Assess the accuracy of the student's prediction.

.....

.....

.....

.....

.....

.....

.....

.....

End of Question 31

Question 32 (5 marks)

Describe how specific experiments have contributed to our understanding of the electron and ONE other fundamental particle. **5**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Question 33 (4 marks)

A proton and an alpha particle are fired into a uniform magnetic field with the same speed from opposite sides as shown. Their trajectories are initially perpendicular to the field. **4**

Explain ONE similarity and ONE difference in their trajectories as they move in the magnetic field.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Question 34 (9 marks)

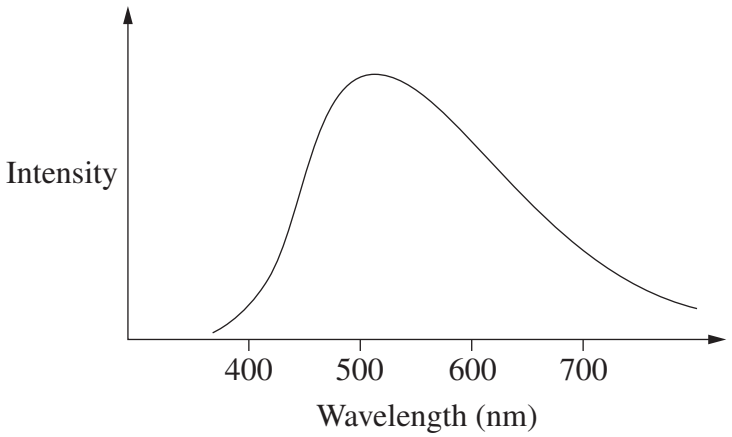
Use the following information to answer this question. **9**

Earth's distance from the sun, r ..... 1.5×10^{11} m

Intensity of solar radiation at a distance r from the sun ..... 1360 W m^{-2}

Surface area of a sphere ..... $4\pi r^2$

Radiation curve for the sun



Describe both the production and radiation of energy by the sun. In your answer, include a quantitative analysis of both the power output and the surface temperature of the sun.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Question 34 continues on page 33

Question 34 (continued)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

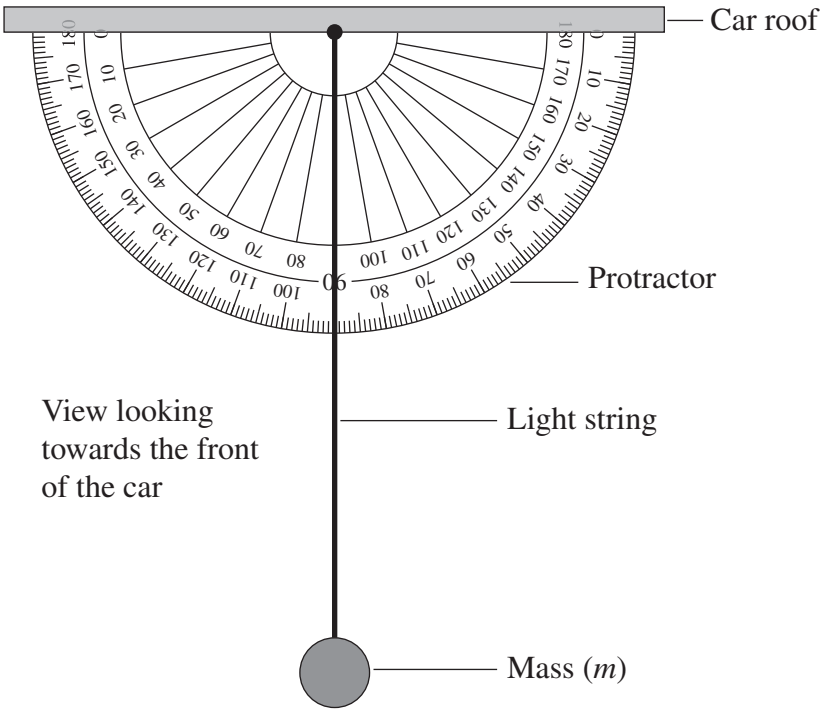
.....

End of Question 34

Please turn over

Question 35 (4 marks)

The apparatus shown is attached horizontally to the roof inside a stationary car. The plane of the protractor is perpendicular to the sides of the car. **4**



The car was then driven at a constant speed (v), on a horizontal surface, causing the string to swing to the right and remain at a constant angle (θ) measured with respect to the vertical.

Describe how the apparatus can be used to determine features of the car's motion. In your answer, derive an expression that relates a feature of the car's motion to the angle θ.

.....

.....

.....

.....

.....

.....

.....

.....

Question 36 (7 marks)

A radon-198 atom, initially at rest, undergoes alpha decay. The masses of the atoms involved are shown in atomic mass units (u). **7**

radon-198	$\longrightarrow$	polonium-194	+	helium-4
197.999 u		193.988 u		4.00260 u

The kinetic energy of the polonium atom produced is 2.55×10^{-14} J.

By considering mass defect, calculate the kinetic energy of the alpha particle, and explain why it is significantly greater than that of the polonium atom.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

End of paper

Section II extra writing space

If you use this space, clearly indicate which question you are answering.

Office Use Only – Do NOT write anything, or make any marks below this line.

2770310369

Do NOT write in this area.

Physics

DATA SHEET

Charge on electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Speed of light, c	3.00×10^8 m s^{-1}
Electric permittivity constant, ε_0	8.854×10^{-12} A^2 s^4 kg^{-1} m^{-3}
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7}$ N A^{-2}
Universal gravitational constant, G	6.67×10^{-11} N m^2 kg^{-2}
Mass of Earth, M_E	6.0×10^{24} kg
Radius of Earth, r_E	6.371×10^6 m
Planck constant, h	6.626×10^{-34} J s
Rydberg constant, R (hydrogen)	1.097×10^7 m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg 931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, ρ	1.00×10^3 kg m^{-3}
Specific heat capacity of water	4.18×10^3 J kg^{-1} K^{-1}
Wien's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

$$s = ut + \frac{1}{2}at^2$$

$$v = u + at$$

$$v^2 = u^2 + 2as$$

$$\vec{F}_{\text{net}} = m\vec{a}$$

$$\Delta U = mg\Delta h$$

$$W = F_{||}s = Fs\cos\theta$$

$$P = \frac{\Delta E}{\Delta t}$$

$$K = \frac{1}{2}mv^2$$

$$P = F_{||}v = Fv\cos\theta$$

$$\sum \frac{1}{2}mv^2_{\text{before}} = \sum \frac{1}{2}mv^2_{\text{after}}$$

$$\sum m\vec{v}_{\text{before}} = \sum m\vec{v}_{\text{after}}$$

$$\Delta\vec{p} = \vec{F}_{\text{net}}\Delta t$$

$$a_{\text{c}} = \frac{v^2}{r}$$

$$\omega = \frac{\Delta\theta}{t}$$

$$F_{\text{c}} = \frac{mv^2}{r}$$

$$\tau = r_{\perp}F = rF\sin\theta$$

$$F = \frac{GMm}{r^2}$$

$$v = \frac{2\pi r}{T}$$

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$U = -\frac{GMm}{r}$$

Waves and thermodynamics

$$v = f\lambda$$

$$f_{\text{beat}} = \left| f_2 - f_1 \right|$$

$$f = \frac{1}{T}$$

$$f' = f\frac{\left(v_{\text{wave}} + v_{\text{observer}}\right)}{\left(v_{\text{wave}} - v_{\text{source}}\right)}$$

$$d\sin\theta = m\lambda$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$n_{\text{x}} = \frac{c}{v_{\text{x}}}$$

$$\sin\theta_{\text{c}} = \frac{n_2}{n_1}$$

$$I = I_{\max}\cos^2\theta$$

$$I_1r_1^2 = I_2r_2^2$$

$$Q = mc\Delta T$$

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

Electricity and magnetism

$$E = \frac{V}{d}$$

$$V = \frac{\Delta U}{q}$$

$$W = qV$$

$$W = qEd$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$B = \frac{\mu_0 NI}{L}$$

$$\Phi = B_{||}A = BA\cos\theta$$

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

$$\frac{V_\mathrm{p}}{V_\mathrm{s}} = \frac{N_\mathrm{p}}{N_\mathrm{s}}$$

$$\vec{F} = q\vec{E}$$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

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

$$V = IR$$

$$P = VI$$

$$F = qv_\perp B = qvB\sin\theta$$

$$F = lI_\perp B = lIB\sin\theta$$

$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$

$$\tau = nIA_\perp B = nIAB\sin\theta$$

$$V_\mathrm{p} I_\mathrm{p} = V_\mathrm{s} I_\mathrm{s}$$

Quantum, special relativity and nuclear

$$\lambda = \frac{h}{mv}$$

$$K_\mathrm{max} = hf - \phi$$

$$\lambda_\mathrm{max} = \frac{b}{T}$$

$$E = mc^2$$

$$E = hf$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_\mathrm{f}^2} - \frac{1}{n_\mathrm{i}^2}\right)$$

$$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$$

$$p_\mathrm{v} = \frac{m_0 v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$N_\mathrm{t} = N_0 e^{-\lambda t}$$

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.