NSW GOVERNMENT

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

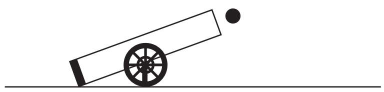
Section I

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?

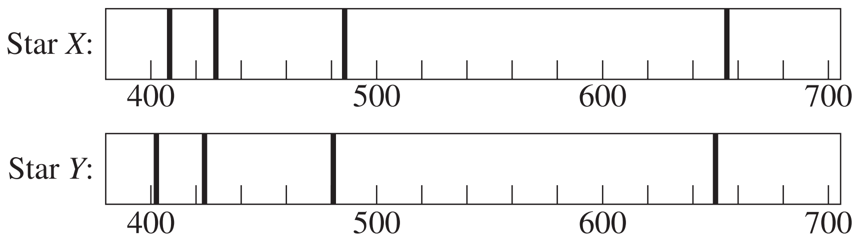
A. ↑

B. ↓

C. ↘

D. →

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

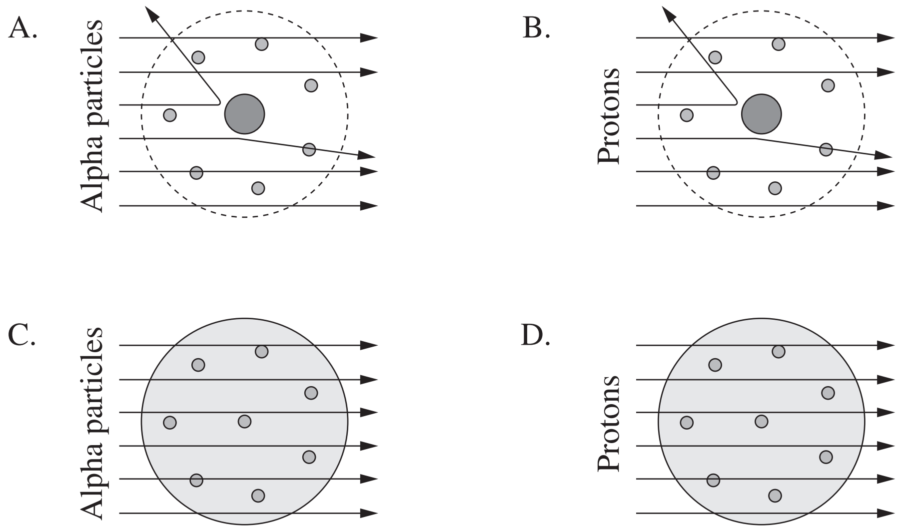


Using these spectra, what can be concluded about the motion of the stars relative to Earth and their chemical compositions?

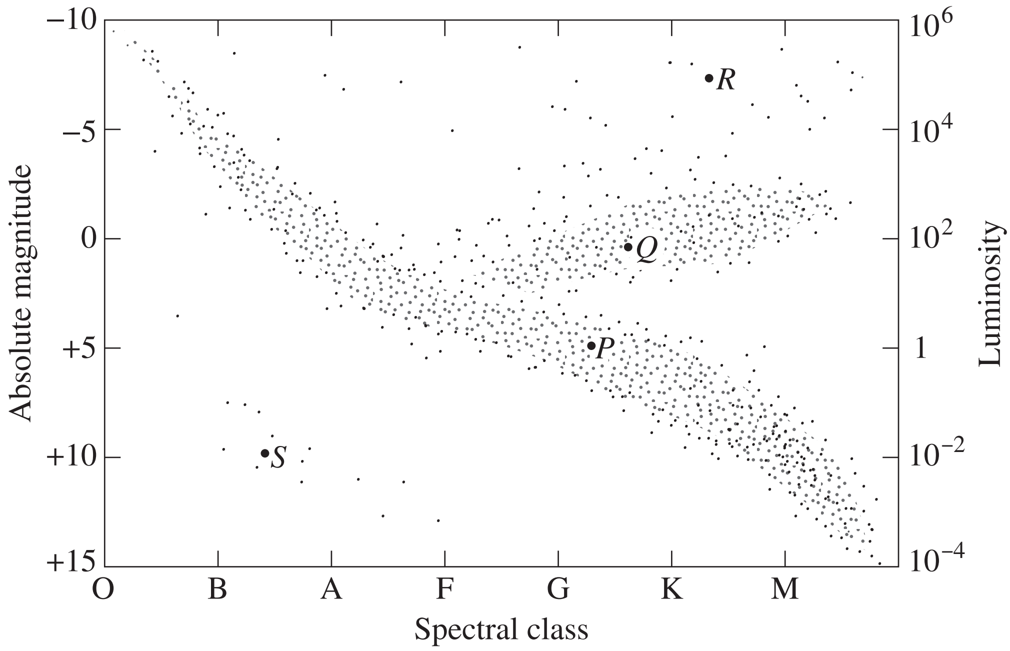
	Motion relative to Earth	*Chemical composition*
A.	The same	The same
B.	Different	The same
C.	The same	Different
D.	Different	Different

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?



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



Which statement is correct?

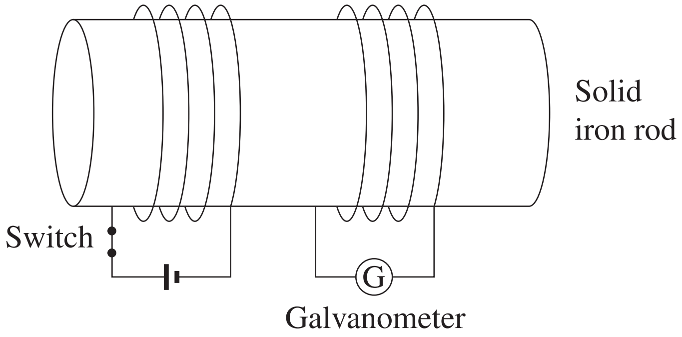
A. S has a greater luminosity than Q.

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.

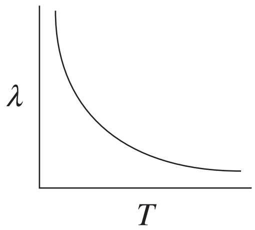
B. move from a non-zero reading to a zero reading.

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

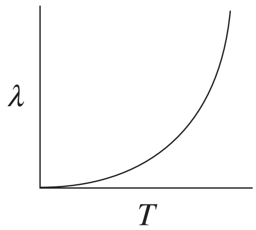
D. move from a zero reading to a non-zero reading, then back to zero.

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?

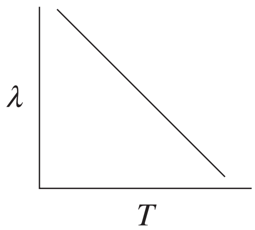
A.



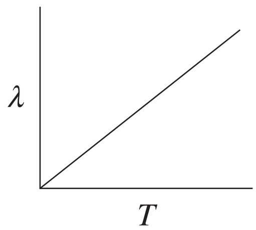
B.



C.



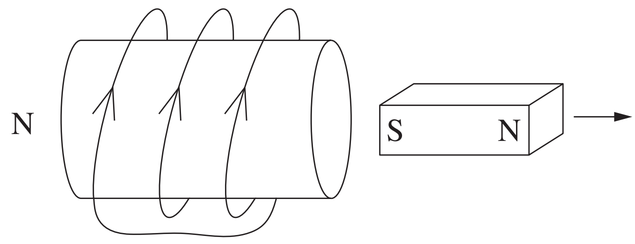
D.



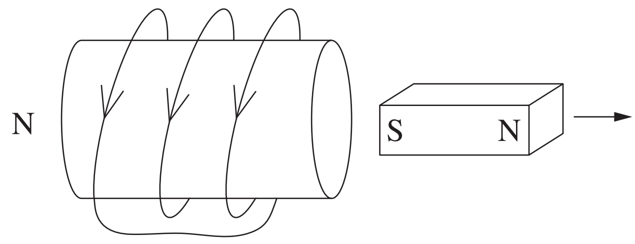
7 A bar magnet is moved away from a stationary coil.

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

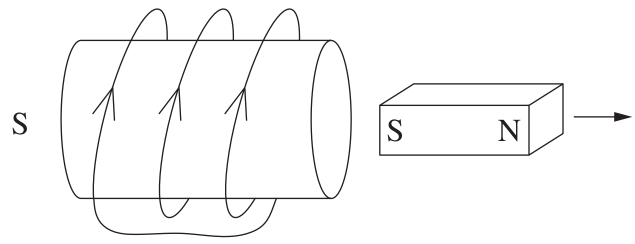
A.



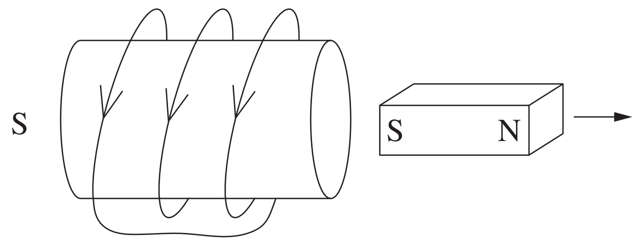
B.



C.

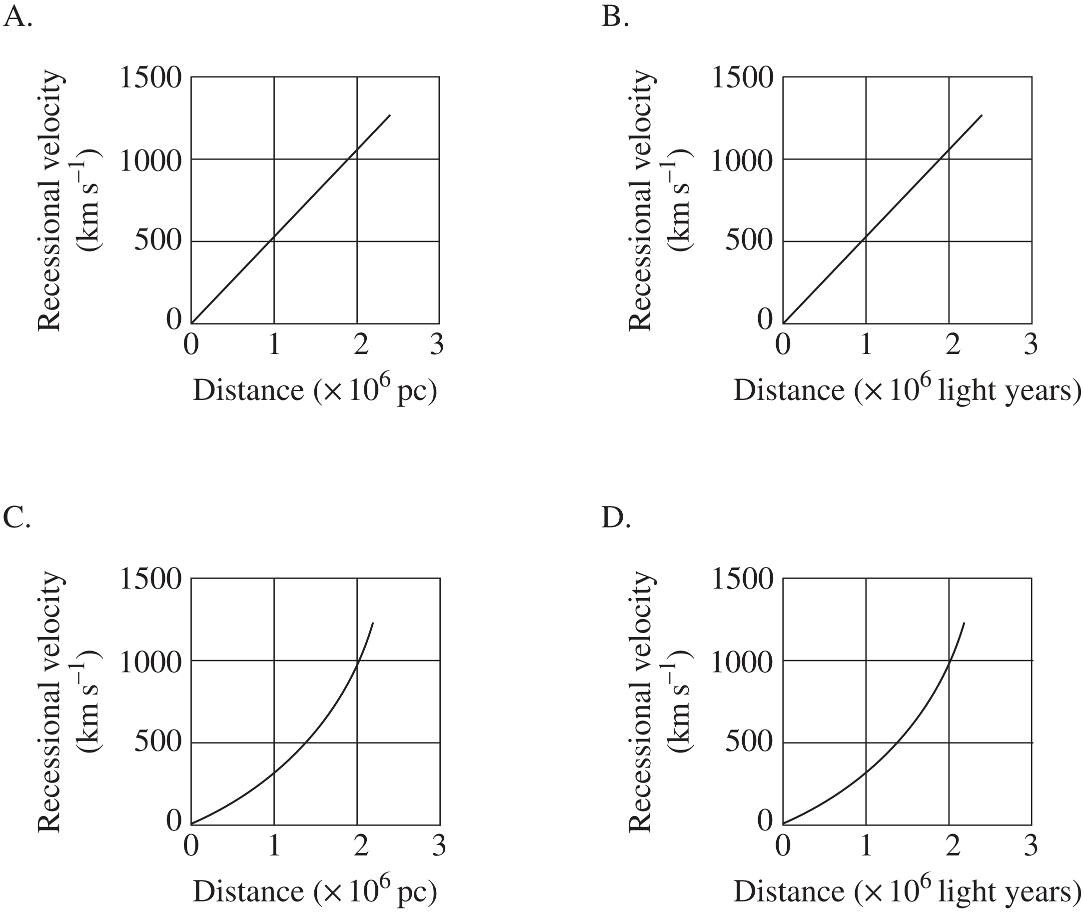


D.



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?



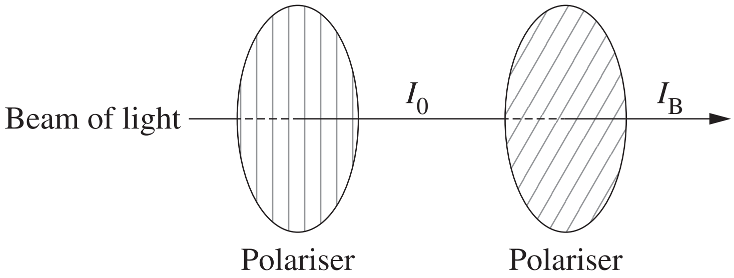
9 Two satellites have the same mass. One (LEO) is in low-Earth orbit and the other (GEO) is in a geostationary orbit.

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?

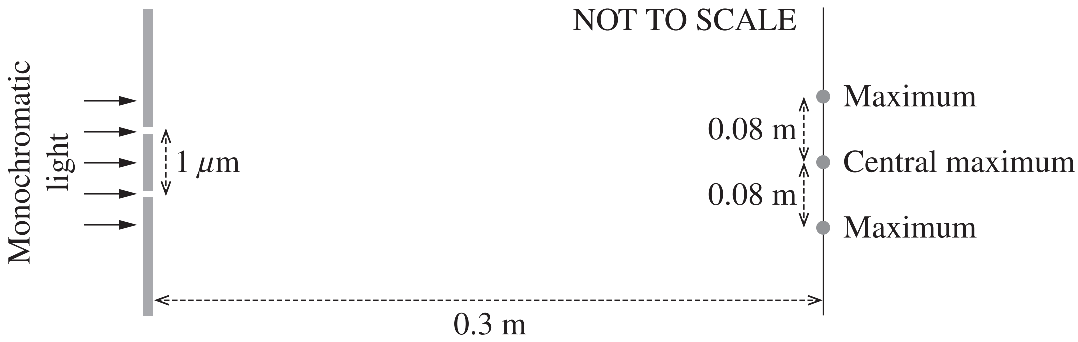
A. $\dfrac{v}{2}$

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.

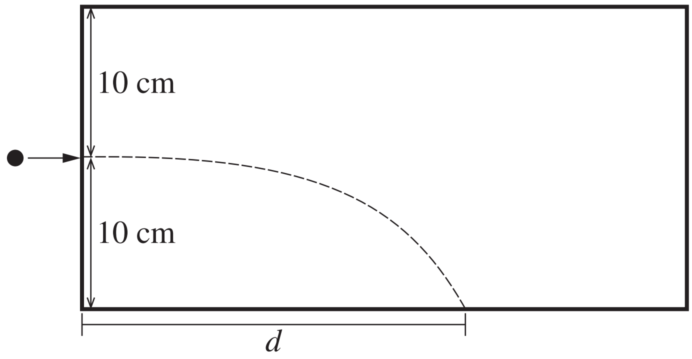


This diffraction pattern can be analysed using the equation $d\sin\theta = \lambda$.

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

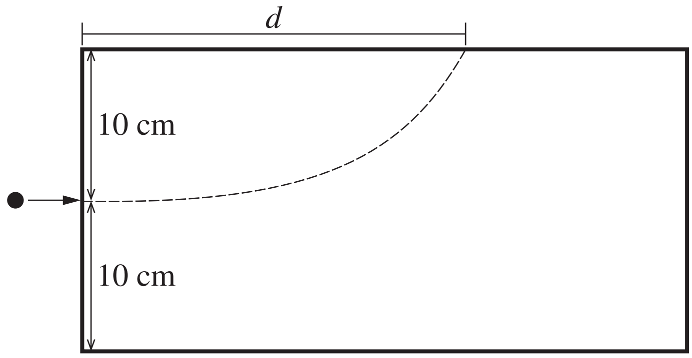
	d	θ
A.	0.3 m	$\tan^{-1}\left(\dfrac{0.08}{0.3}\right)$
B.	0.3 m	$\sin^{-1}\left(\dfrac{0.08}{0.3}\right)$
C.	$1\ \mu m$	$\tan^{-1}\left(\dfrac{0.08}{0.3}\right)$
D.	$1\ \mu m$	$\sin^{-1}\left(\dfrac{0.08}{0.3}\right)$

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?

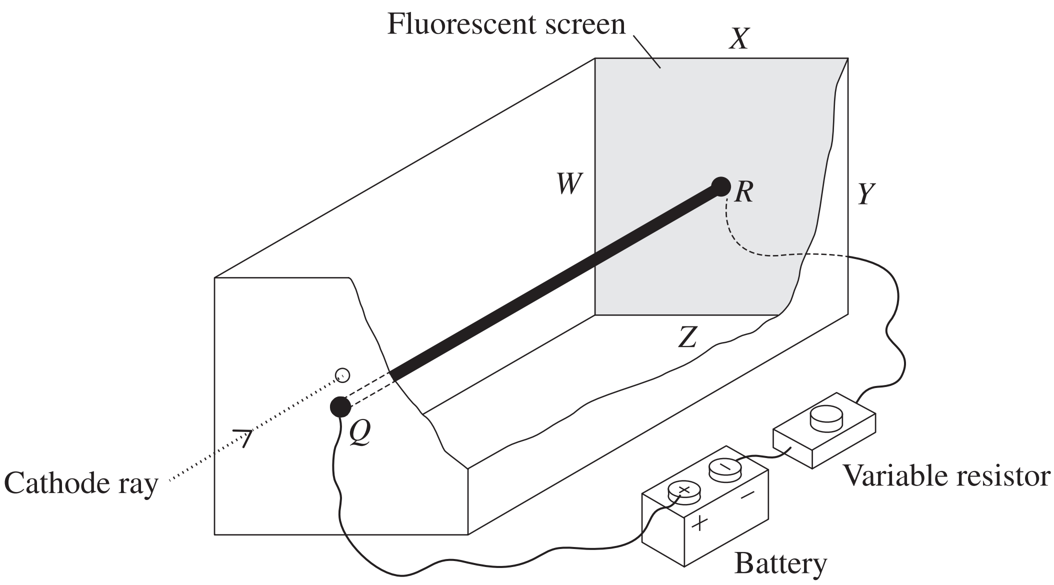
A. mgq

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?

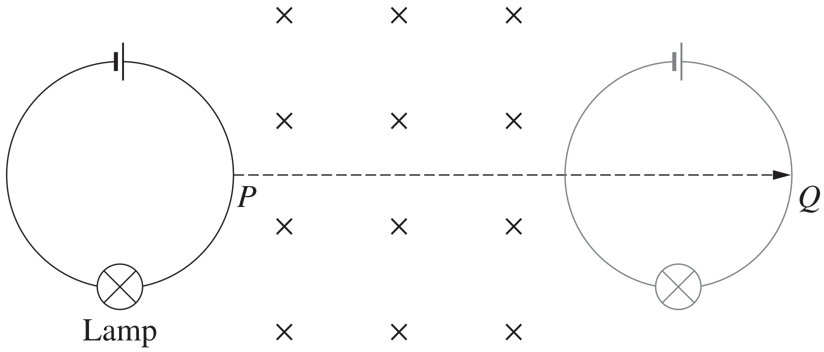
A. *W*

B. *X*

C. *Y*

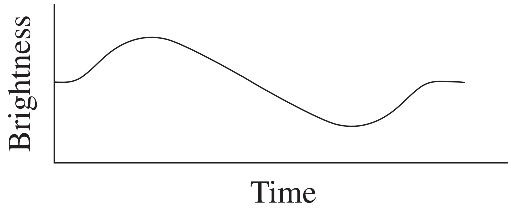
D. *Z*

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.

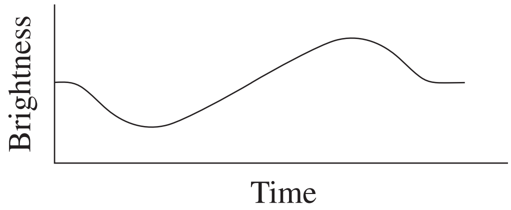


Which graph shows the brightness of the lamp as the apparatus moves between P and Q?

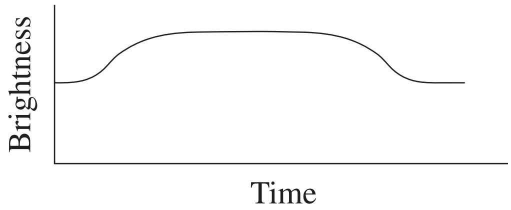
A.



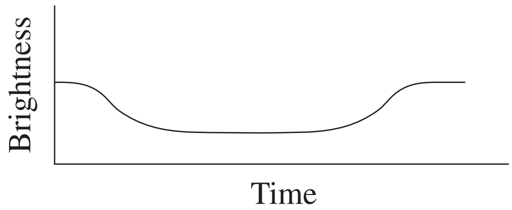
B.



C.



D.



19 Consider the following nuclear reaction.

$$\mathrm{W} + \mathrm{X} \rightarrow \mathrm{Y} + \mathrm{Z}$$

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.

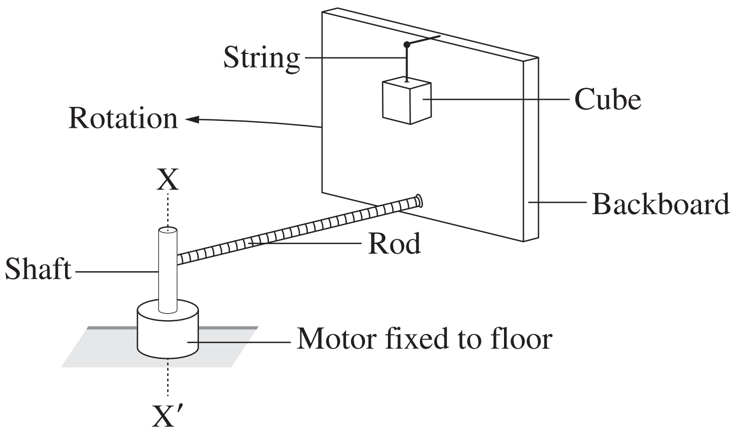
B. It cannot be deduced whether the reaction releases energy because the properties of Z are not known.

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

Do NOT write in this area.

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.

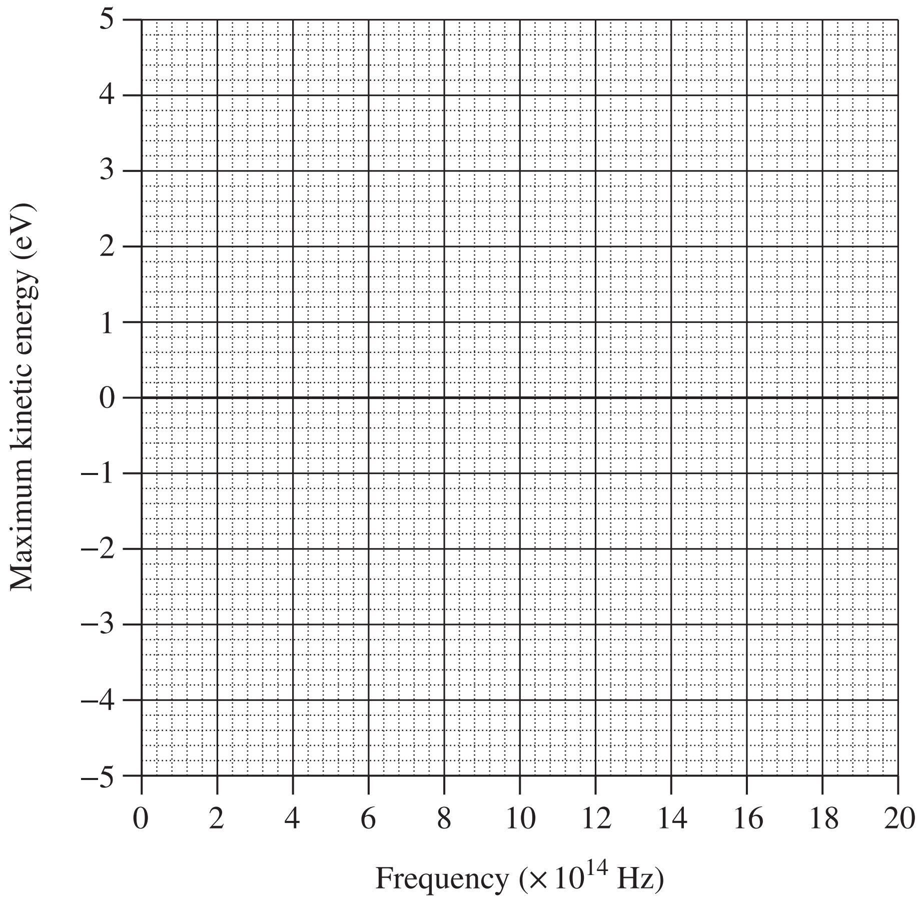
Question 23 (3 marks)

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.



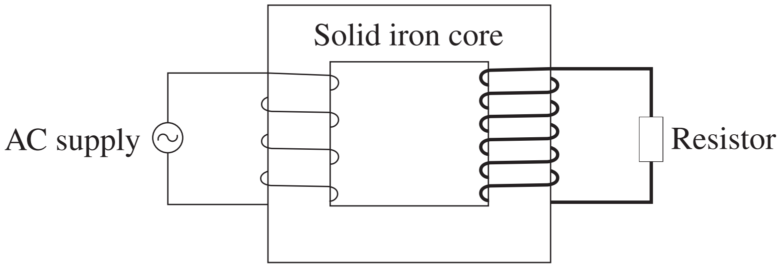
....

....

....

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_pI_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**

....

....

....

....

....

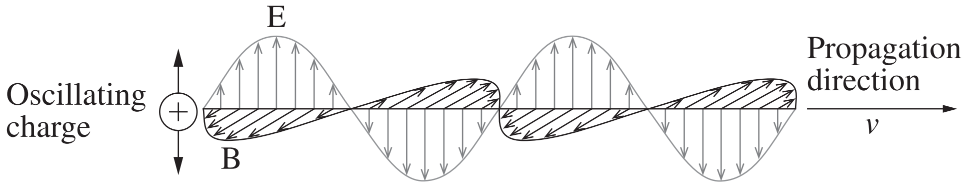
....

....

....

Question 25 (4 marks)

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



Relate this model to predictions made by Maxwell.

....

....

....

....

....

....

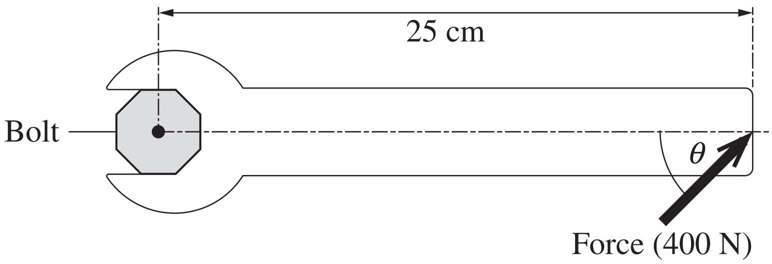
....

....

Please turn over

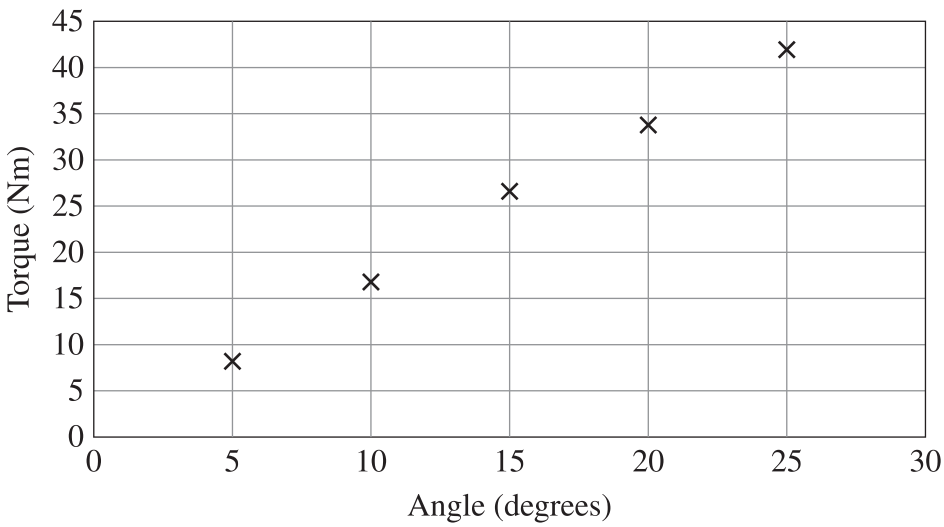
Question 26 (6 marks)

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**

....

....

....

....

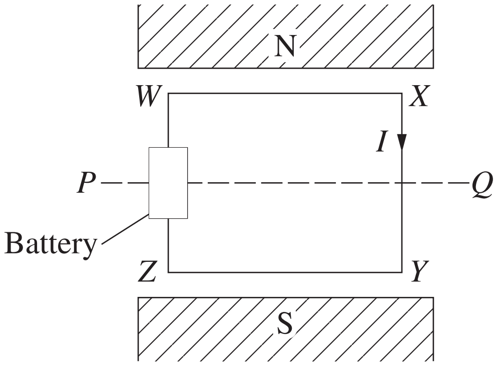
....

....

Do NOT write in this area.

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.

....

....

....

....

....

....

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 $v = \sqrt{\dfrac{2qV}{m}}$.

....

....

....

....

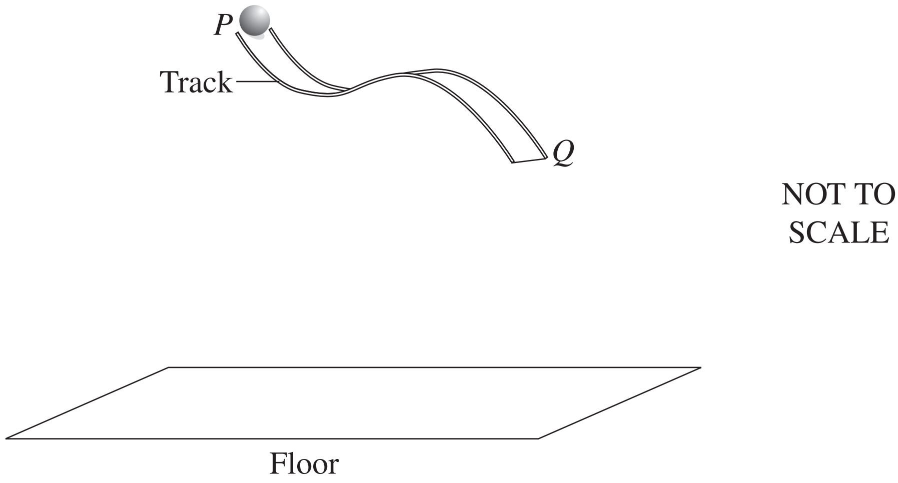
....

Do NOT write in this area.

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.



At the instant the ball leaves the track at Q it has a velocity of $1.5\ \mathrm{m\,s^{-1}}$ 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.

....

....

....

....

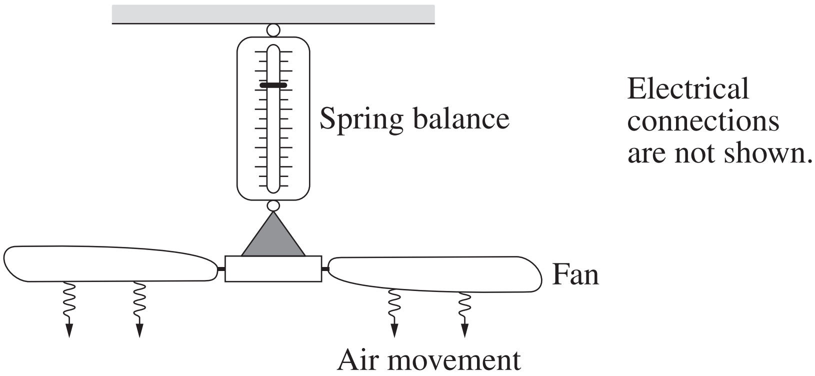
....

....

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**

....

....

....

....

....

....

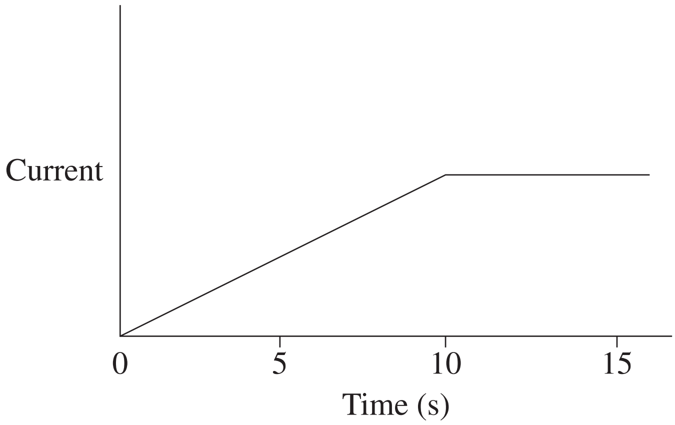
....

....

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**

....

....

....

....

....

....

....

....

....

....

....

....

....

....

Do NOT write in this area.

Do NOT write in this area.

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.

....

....

....

....

....

....

....

....

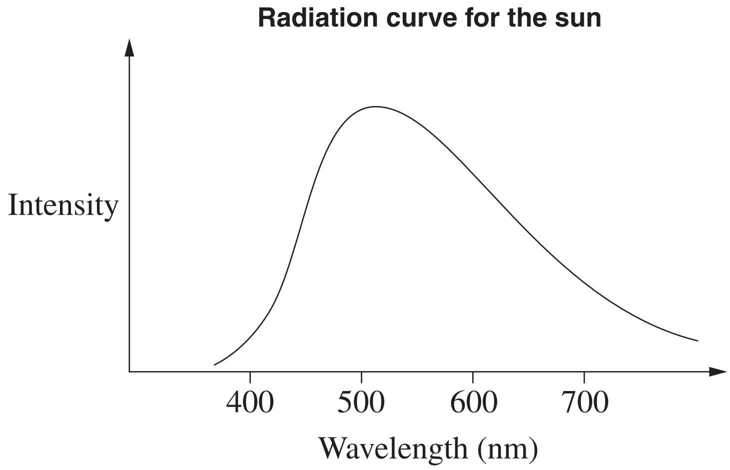
....

....

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 .... $4\pi r^2$



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

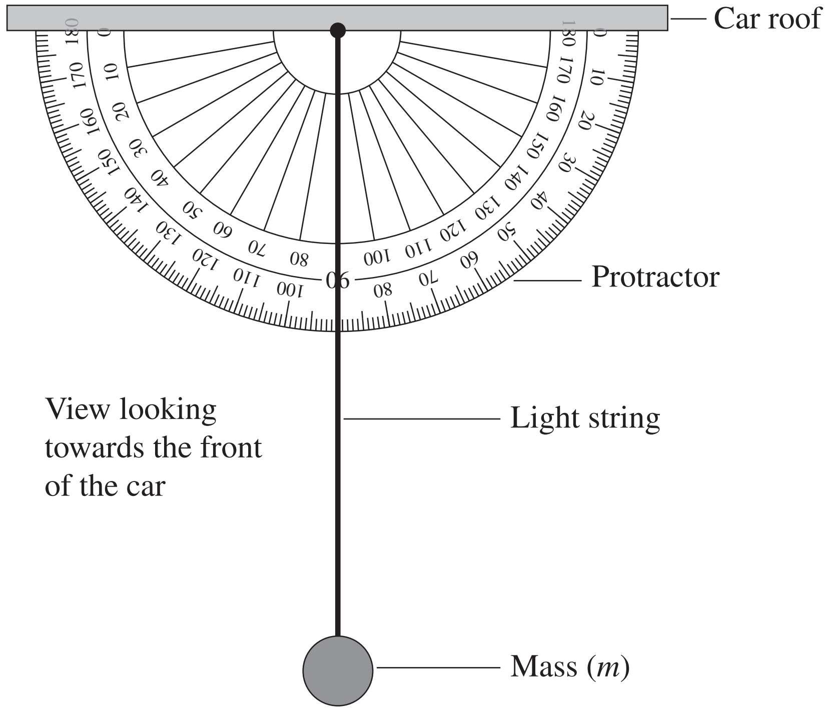
Question 34 (continued)

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.

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

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

$v = u + at$

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

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

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

$\Delta U = mg\Delta h$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$W = qV$$

$$W = qEd$$

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

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

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

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

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

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

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

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

$$V = IR$$

$$P = VI$$

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

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

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

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

$$V_p I_p = V_s I_s$$

Quantum, special relativity and nuclear

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

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

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

$$E = mc^2$$

$$E = hf$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

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

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

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

$$N_t = N_0 e^{-\lambda t}$$

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

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.

2019 HSC Physics
Marking Guidelines

Section I

Multiple-choice Answer Key

Question	Answer
1	D
2	B
3	C
4	C
5	D
6	A
7	D
8	A
9	D
10	A
11	C
12	A
13	B
14	B
15	C
16	D
17	D
18	B
19	D
20	B

Section II

Question 21

Criteria	Marks
• Refers to de Broglie's characterisation of the wave nature of matter • Refers to a relevant equation	2
• Refers to de Broglie's characterisation of the wave nature of matter OR • Refers to a relevant equation	1

Sample answer:

It was postulated by de Broglie that particles, such as electrons, possess wave properties. The wavelength associated with such particles is predicted by:

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

Question 22

Criteria	Marks
• Relates observations to features of stars	3
• Relates an observation to a feature of a star	2
• Identifies an observation or other feature of a star	1

Sample answer:

Absorption spectra can reveal information about the density of a star. Darker, broader spectral lines indicate significant levels of absorption associated with denser stars, whereas fainter, narrower spectral lines are associated with less dense stars.

The frequency of lines in absorption spectra can reveal information about the motion of a star. A shift towards lower frequencies indicates that the star is moving away from the observer.

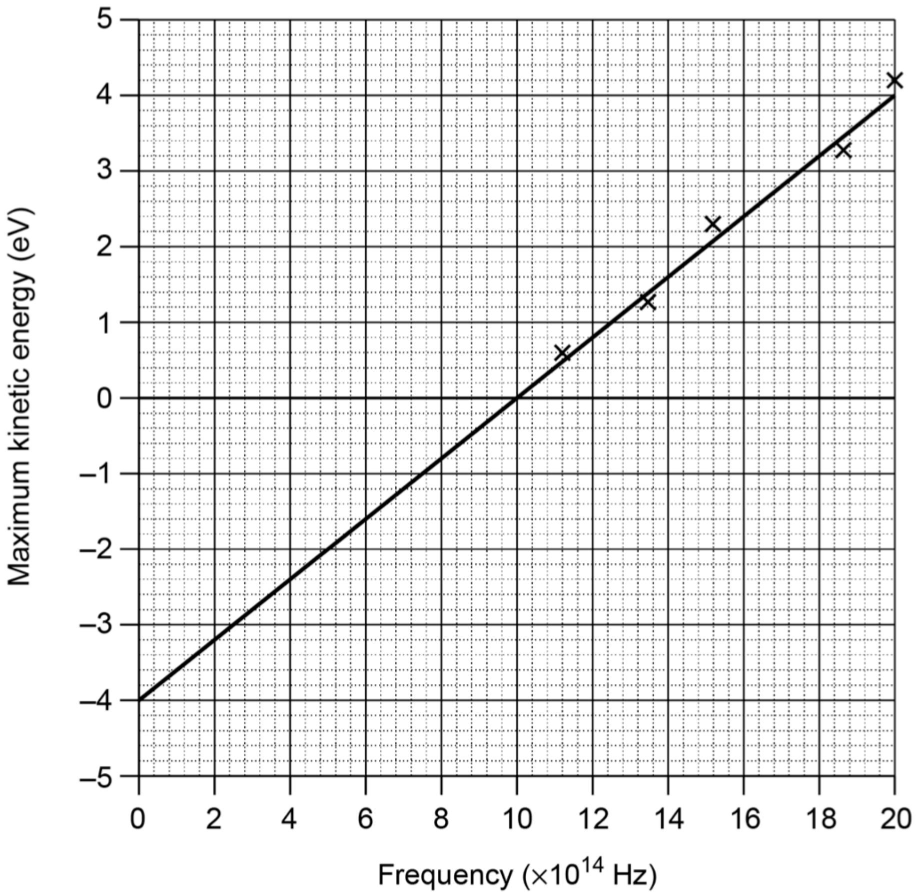
Answers may include:

Red and blue shifts from the edges of a star's light disc which can provide information about its rotational velocity. Binary/multiple star systems.

Question 23

Criteria	Marks
• Determines the correct work function using the line of best fit	3
• Plots the values on the graph • Draws a line of best fit or determines work function from the graph	2
• Correctly plots some points OR • Correctly draws a line of best fit	1

Sample answer:



The work function of the metal is 4 eV.

Answers could include:

Calculation based on the threshold frequency.

Question 24 (a)

Criteria	Marks
• Explains how the operation of the transformer is consistent with conservation of energy • Includes a relevant calculation	3
• Relates transformer input and output using power or energy calculations	2
• Provides some relevant information	1

Sample answer:

The energy input is 500 J s^{-1}.

The electrical energy output is $V_s I_s$ per second = 450 J s^{-1}

To be consistent with the law of conservation of energy, 50 J s^{-1} of energy must be converted into other forms, such as heat.

Question 24 (b)

Criteria	Marks
• Explains how modifications improve efficiency	4
• Explains how a modification improves efficiency and identifies a second modification OR • Outlines how modifications improve efficiency	3
• Identifies modifications OR • Outlines how a modification improves efficiency	2
• Provides some relevant information	1

Sample answer:

The iron core could be laminated. Laminations reduce the magnitude of the induced eddy currents, minimising energy loss.

The thicker wire could be used in the primary coil rather than the secondary coil to decrease the resistance where there is a higher current, and hence reduce energy lost as heat.

Both modifications would increase its efficiency.

Question 25

Criteria	Marks
• Relates the model to predictions made by Maxwell	4
• Relates the model to a prediction made by Maxwell • Identifies another prediction made by Maxwell or another feature of the model	3
• Identifies prediction(s) made by Maxwell AND/OR • Identifies feature(s) of the model	2
• Provides some relevant information	1

Sample answer:

The model shows alternating electric and magnetic fields perpendicular to each other. This is consistent with Maxwell's prediction that a changing electric field produces a changing magnetic field and vice versa.

The model shows a wave propagating at velocity v. Maxwell predicted the existence of a range of waves with different wavelengths, all travelling with the same speed.

Answers could include:

The model shows an oscillating charge and an e/m wave emanating from it. This is consistent with Maxwell's prediction that an oscillating charge produces an e/m wave.

Ways in which this model differs from Maxwell's predications.

Question 26 (a)

Criteria	Marks
• Provides reasons for the validity of the model	3
• Provides a reason for the validity of the model	2
• Provides some relevant information	1

Sample answer:

The graph shows a linear relationship with a gradient of 1.7, consistent with the model $\tau = k\theta$. The model can be used to accurately predict the torque at any angle within the range of angles measured.

Question 26 (b)

Criteria	Marks
• Justifies an increasing reduction in the student's model's accuracy using another model	3
• Outlines a reduction in the model's accuracy using another model	2
• Identifies a feature of an alternative model OR • Identifies a reduction in the model's accuracy	1

Sample answer:

The torque produced by a force is more accurately described by $\tau = rF\sin\theta$, which predicts values of torque smaller than those predicted by the student's model. The discrepancy between the models increases as the angle is increased.

Question 27 (a)

Criteria	Marks
• Outlines a thought experiment related to the prediction of time dilation	3
• Provides features of a relevant thought experiment	2
• Identifies a thought experiment or a feature of time dilation	1

Sample answer:

Imagine a person on a train travelling at near the speed of light with a light pulse that bounces up and down between two mirrors. An observer outside the train sees the light pulse travel in a triangular path. This path is longer than that observed by the person on the train. Since the speed of light is constant for both observers, their measured times would be different. The observer outside the train observes a longer time demonstrating time dilation.

Question 27 (b)

Criteria	Marks
• Outlines experimental evidence that validates time dilation	3
• Outlines a relevant experiment	2
• Provides some relevant information	1

Sample answer:

Measurements of the decay time of muons produced by cosmic rays in the upper atmosphere, and traveling >0.99c, were made on top of a mountain and at sea level. The data from the mountain top allowed the number of muons that would be observed at sea level, assuming no relativistic effects, to be predicted. The actual number observed at sea level was greater that this model predicted, and was consistent with the increase in the muons' half-life, predicted by taking time dilation into account, thus validating the prediction of time dilation.

Answers could include:

- Evidence from atomic clocks on planes
- Evidence from particle accelerators, or
- Evidence from cosmological studies.

Question 28

Criteria	Marks
• Compares the forces acting on *WX* and *XY* before and after the rotation	3
• Identifies some features of the forces acting on *WX* and *XY* OR • Compares the forces acting on *WX* or *XY* before and after the rotation	2
• Identifies a feature of the force acting on *WX* or *XY*	1

Sample answer:

The magnitude and direction of the force on *WX* remains the same when it is rotated. Initially, *XY* experiences no force, whereas after rotation it experiences a force to the right.

Question 29

Criteria	Marks
• Correctly derives the relationship	3
• Shows some correct steps or reasoning	2
• Provides some relevant information	1

Sample answer:

The work done is equal to the change in kinetic energy.

$\therefore W = \Delta K$

$$qV = \frac{1}{2}mv^2 - 0$$

$$\therefore v = \sqrt{\left(\frac{2qV}{m}\right)}$$

Answers could include:

Use of calculus.

Question 30 (a)

Criteria	Marks
• Correctly calculates the difference in height	3
• Provides some relevant steps	2
• Provides some relevant information	1

Sample answer:

$$\Delta U = \Delta K$$

$$mg\Delta h = \frac{1}{2}\ mv^2$$

$$\Delta h = \frac{v^2}{2\ g}$$

$$= \frac{1.5^2}{2 \times 9.8}$$

$$= 0.1145\ \text{m}$$

Height is 0.11 m

Question 30 (b)

Criteria	Marks
• Correctly calculates the height	3
• Provides some relevant steps	2
• Provides some relevant information	1

Sample answer:

$$u_y = u\sin\theta$$
$$= 1.50 \sin 50$$
$$= 1.15 \text{ m s}^{-1} \text{ downward}$$

$$s = ut + \frac{1}{2}at^2$$
$$= -1.15 \times 0.5 + \frac{1}{2}(-9.80) \times 0.5^2$$
$$= 1.8 \text{ m}$$

Height is 1.8 m

Question 31 (a)

Criteria	Marks
• Explains the changes observed on the spring balance	4
• Explains a change observed on the spring balance OR • Relates changes observed on the spring balance to forces acting on the fan	3
• Identifies changes observed on the spring balance and/or forces acting on the fan	2
• Provides some relevant information	1

Sample answer:

After being switched on, the fan exerts a downward force on the air and due to Newton's 3rd Law an equal upward force is exerted on the fan by the air. This reduces the net vertical force observed on the spring balance. This effect increases as the fan's speed increases.

Since the fan increases in speed until reaching its maximum after 10 seconds, the force observed on the spring balance will decrease until it reaches a minimum at ten seconds, after which it remains constant because the forces are balanced.

Question 31 (b)

Criteria	Marks
• Assesses features of the prediction	4
• Assesses a feature of the prediction OR • Outlines issues with the prediction	3
• Outlines an issue with the prediction	2
• Provides some relevant information	1

Sample answer:

Between 0–10 s the student's prediction incorrectly shows an increasing current. During this time the magnitude of back emf in the motor is increasing, therefore reducing the current in the motor.

From 10–15 s the student's prediction correctly shows a constant current. Since the fan has reached a constant speed, the magnitude of the back emf is also constant, so the net current in the motor is constant.

Question 32

Criteria	Marks
• Presents features of relevant experiments and how their results increased our understanding	5
• Presents feature(s) of relevant experiments and how their results increased our understanding	4
• Presents features of a relevant experiment and how the result increased our understanding OR • Presents feature(s) of relevant experiments	3
• Identifies a relevant experiment and its result or its effect on our understanding	2
• Provides some relevant information	1

Sample answer:

In an experiment, the velocity of charged oil droplets moving under the influence of gravitational and electric fields was measured. Discrete differences in velocity were observed, providing evidence to determine the charge on an electron.

Other fundamental particles include quarks. In one experiment, an accelerated beam of electrons was fired at protons. Scattering patterns produced were interpreted to show that the protons they struck consisted of three smaller particles, later named quarks.

Answers could include:

Experimental evidence showing properties of cathode rays in glass tubes, electron properties such as charge : mass ratio or wave properties.

Experiments which revealed information about second or third generation quarks (strange, charm, top, bottom).

Question 33

Criteria	Marks
• Explains a similarity and a difference	4
• Explains a similarity or a difference AND • Outlines the other	3
• Explains a similarity or a difference OR • Outlines a similarity and a difference	2
• Provides some relevant information	1

Sample answer:

Similarity – both particles will experience a force perpendicular to both their velocity and the magnetic field lines. This will result in both particles experiencing circular motion (in a clockwise direction).

Difference – since the radius is proportional to the mass and inversely proportional to the charge of the particle, the radius of the alpha particle trajectory is greater.

Answers could include:

Sketches the diagram in the question.

Difference related to $r = \dfrac{mv}{qB}$ or other equation.

Question 34

Criteria	Marks
• Describes the production and radiation of energy • Provides quantitative analysis of power output and surface temperature	9
• Describes aspects of the production and radiation of energy • Provides aspects of quantitative analysis of power output and surface temperature	7–8
• Describes aspect(s) of the production and radiation of energy • Provides aspects of quantitative analysis of power output or surface temperature OR • Describes aspects of the production or radiation of energy • Provides aspects of quantitative analysis of power output and surface temperature	5–6
• Outlines aspect(s) of the production and/or radiation of energy AND/OR • Provides aspect(s) of quantitative analysis of power output and/or surface temperature	3–4
• Identifies aspect(s) of the production and/or radiation of energy	1–2

Sample answer:

Most of the sun's energy is produced by the proton-proton chain fusion reactions which convert hydrogen into helium via intermediate reactions involving the formation of deuterium and helium. During this process mass is converted to energy.

The sun acts like a black body and its radiation is characterised by a black body curve. Energies are determined by the wavelength of the radiation. It peaks at a specific wavelength which characterises its temperature.

The sun's surface is a black body radiator with a temperature T where
$\lambda_{max} = b/T$

$\lambda_{max} = 5.00 \times 10^{-7}$ m from the graph

Hence $T = b/\lambda_{max} = 2.898 \times 10^{-3} / 5.0 \times 10^{-7} = 5800$ K

Total power output (P) of the sun is $P = IA = I \times 4\pi r^2$

where I = intensity at Earth's distance (r) = 1360 W m^{-2}

and $r = 1.5 \times 10^{11}$ m

Total power output of sun $P = I \times 4\pi r^2 \pi r^2 = 1360 \times 4 \times 3.142 \times (1.5 \times 10^{11})^2 = 3.85\ 10^{26}$ W

Answers could include:

Quantitative analysis relating the calculated power and $E = mc^2$ in lieu of proton–proton chain.

Question 35

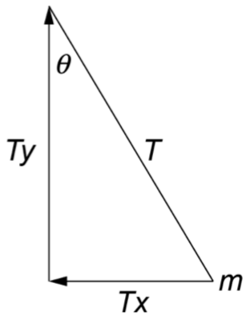
Criteria	Marks
• Relates observations to features of the car's motion • Derives an expression that relates the radius in terms of θ	4
• Relates observations to features of the car's motion • Provides some steps toward determining an expression for a feature of the motion in terms of θ	3
• Relates an observation to a features of the car's motion	2
• Provides some relevant information	1

Sample answer:

The constant deflection of the pendulum to the right indicates that the car has a uniform acceleration to the left, and is therefore travelling in uniform circular motion.

Larger values of θ indicate smaller radii of motion.

The radius of motion can be expressed in terms of θ:



① $$Ty = T\cos\theta = mg$$

② $$Tx = T\sin\theta = ma = \frac{mv^2}{r}$$

from ① $$T = \frac{mg}{\cos\theta}$$

in ② $$\frac{mg\sin\theta}{\cos\theta} = \frac{mv^2}{r}$$

$$\therefore\ g\tan\theta = \frac{v^2}{r}$$

$$r = \frac{v^2}{g\tan\theta}$$

Question 36

Criteria	Marks
• Applies correct method to calculate KE of the alpha particle • Explains the greater KE of the alpha particle using the principle of conservation of momentum	7
• Applies correct method to calculate KE of the alpha particle • Applies the principle of conservation of momentum	6
• Shows the main steps of the calculation of KE AND/OR • Shows a sound understanding of the conservation of momentum	4–5
• Shows step(s) of the calculation of KE AND/OR • Shows some understanding of the conservation of momentum	2–3
• Provides some relevant information	1

Sample answer:

Alpha decay

Mass defect $= 197.999 - (193.988 + 4.000260) = 0.0084$u

Converting to kilograms $= 0.0084 \times 1.661 \times 10^{-27} = 1.395 \times 10^{-29}$ kg

Total energy produced $= mc^2 = 1.395 \times 10^{-29} \times (3 \times 10^8)^2 = 1.256 \times 10^{-12}$ J

KE_{alpha} = Total Energy produced – $KE_{polonium} = 1.256 \times 10^{-12} - 2.44 \times 10^{-14}$

$= 1.23 \times 10^{-12}$ J

Since the radon atom is initially at rest, the decay products move away from each other with equal and opposite momenta. As the alpha particle's mass is significantly less than that of the polonium atom, it therefore has a significantly higher velocity ($p = mv$), and consequently a higher KE. Despite the higher mass of the polonium atom, the higher velocity of the alpha particle has a more significant effect on its KE ($KE = \frac{1}{2} mv^2$).

Answers could include:

Calculation not using mass defect ($K \rightarrow P$).

2019 HSC Physics Mapping Grid

Section I

Question	Marks	Content	Syllabus outcomes
1	1	M5 Projectile Motion	12-6, 12-12
2	1	M7 Electromagnetic Spectrum	12-5, 12-6, 12-14
3	1	M8 Structure of the Atom	12-6, 12-15
4	1	M8 Origins of the Elements	12-5, 12-6
5	1	M6 Electromagnetic Induction	12-6, 12-13
6	1	M7 Light: Quantum Model	12-6, 12-14
7	1	M6 Applications of the Motor Effect	12-6, 12-13
8	1	M8 Origins of the Elements	12-5, 12-6
9	1	M5 Motion in Gravitation Fields	12-6, 12-12
10	1	M7 Light: Wave Model	12-6, 12-14
11	1	M5 Motion in Gravitational Fields	12-6, 12-12
12	1	M8 Deep inside the Atom	12-6, 12-15
13	1	M7 Light: Quantum Model M8 Quantum Mechanical Nature of the Atom	12-6, 12-14
14	1	M5 Motion in Gravitation Fields	12-6, 12-12
15	1	M7 Light: Wave Model	12-6, 12-14
16	1	M6 Charged Particles, Conductors, Electric and Magnetic Fields	12-6, 12-12
17	1	M6 Motor Effect	12-6, 12-13
18	1	M6 Applications of the Motor Effect	12-6, 12-13
19	1	M8 Properties of the Nucleus	12-6, 12-15
20	1	M5 Circular Motion	12-6, 12-12

Section II

Question	Marks	Content	Syllabus outcomes
21	2	M8 Quantum Mechanical, Nature of the Atom	12-15, 12-6
22	3	M7 Electromagnetic Spectrum	12-14, 12-6
23	3	M7 Light: Quantum Model	12-4, 12-14, 12-5, 12-6
24 (a)	3	M6 Electromagnetic Induction	12-13, 12-6
24 (b)	4	M6 Electromagnetic Induction	12-13, 12-6
25	4	M7 Electromagnetic spectrum	12-14, 12-6
26 (a)	3	M5 Circular Motion	12-4, 12-12, 12-5, 12-6
26 (b)	3	M5 Circular Motion	12-5, 12-12, 12-6
27 (a)	3	M7 Light and Special Relativity	12-14, 12-6
27 (b)	3	M7 Light and Special Relativity	12-14, 12-6
28	3	M6 Motor Effect	12-13, 12-6

Question	Marks	Content	Syllabus outcomes
29	3	M6 Charged Particles, Conductors and Electric and Magnetic Fields	12-6, 12-13, 12-6
30 (a)	3	M5 Projectile Motion	12-6, 12-12, 12-6
30 (b)	3	M5 Projectile Motion	12-6, 12-12, 12-6
31 (a)	4	M5 Circular Motion, Motion in Gravitational Field	12-12, 12-6
31 (b)	4	M6 Applications of the Motor Effect	12-5, 12-13, 12-6
32	5	M8 Structure of the Atom, Deep Inside the Atom	12-15, 12-6
33	4	M6 Charged Particles, Conductors and Electric and Magnetic Fields	12-6, 12-13, 12-6
34	9	M7 Light: Quantum Model M8 Properties of the Nucleus	12-14, 12-15, 12-6
35	4	M5 Circular Motion	12-2, 12-12, 12-6
36	7	M8 Properties of the Nucleus	12-15, 12-6