Rewarding Learning

Centre Number

71	

Candidate Number

ADVANCED
General Certificate of Education
2014

Physics

Assessment Unit A2 1

assessing

Momentum, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics

[AY211]

AY211

TUESDAY 20 MAY, MORNING

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all eleven** questions.
Write your answers in the spaces provided in this question paper.

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.
Quality of written communication will be assessed in Question **9**.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.

For Examiner's use only	
Question Number	Marks
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
Total Marks	

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If you need the values of physical constants to answer any questions in this paper they may be found in the Data and Formulae Sheet.

Examiner Only	
Marks	Remark

Answer **all eleven** questions.

1 Polonium-210 decays to lead-206 by the emission of an alpha particle as shown in **Equation 1.1**.

$$^{210}_{84}Po \rightarrow\ ^{206}_{82}Pb + \alpha$$ **Equation 1.1**

(a) Calculate the momentum of the alpha particle if it is emitted with velocity of $+1.60 \times 10^4$ m s^{-1}, has a charge of $+3.20 \times 10^{-19}$ C and a mass of 6.64×10^{-27} kg.

Momentum = ____________________ kg m s^{-1} [1]

(b) If the polonium nucleus is stationary when the decay occurs, what is the initial velocity of the lead nucleus after the decay? State the direction of motion relative to the α-particle.

Velocity = ____________________ m s^{-1}

Direction = ____ [4]

(c) State whether this decay is elastic or inelastic and explain your answer with specific reference to this decay.

____

____ [2]

2 The graph in **Fig. 2.1** was drawn using data obtained from an experiment carried out on a fixed mass of gas at constant temperature. The y-axis label refers to the length of the tube of uniform cross-sectional area occupied by the gas.

Examiner Only	
Marks	Remark

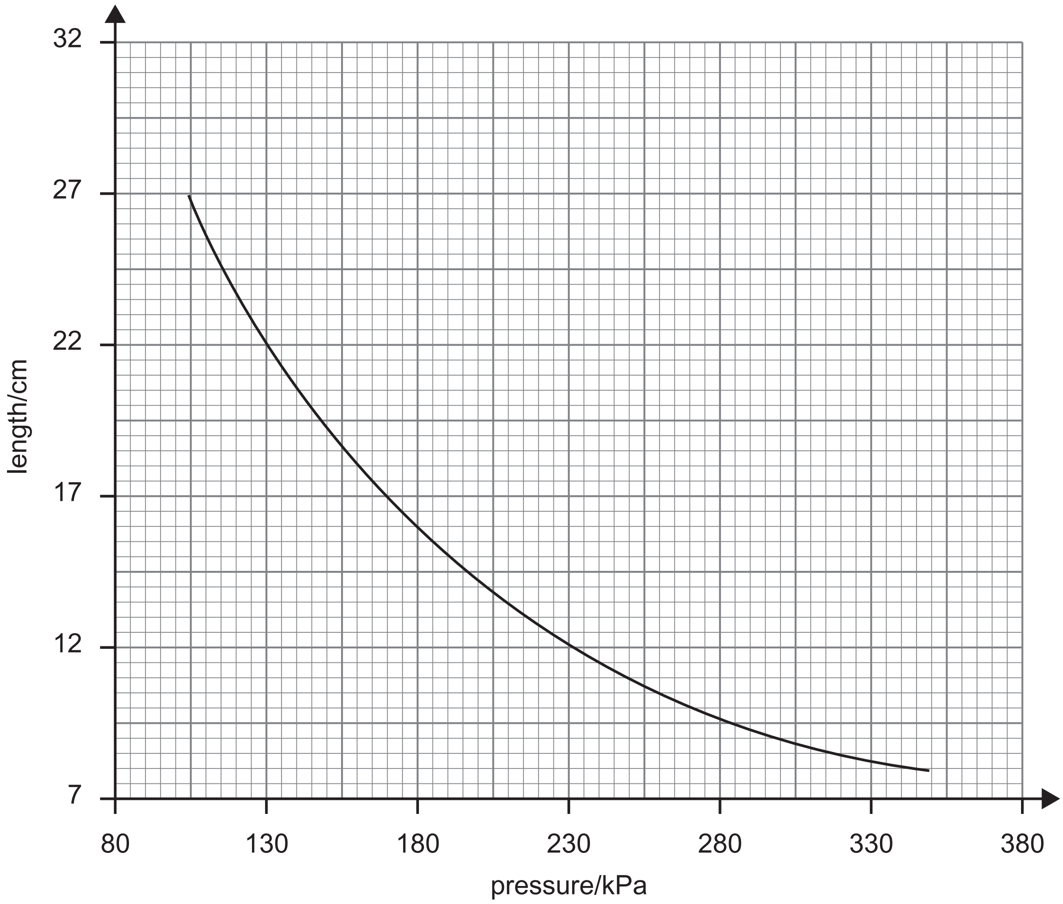

Fig. 2.1

(a) (i) Describe, with the help of a labelled sketch, the apparatus used to obtain the data from which the graph in **Fig. 2.1** can be drawn.

[3]

(ii) When the gas is compressed the kinetic energy of the gas molecules increases. Explain why this is undesirable and suggest an experimental procedure that would counteract the increase.

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____ [2]

(b) The data used for the graph in **Fig. 2.1** can also be used to plot the graph in **Fig. 2.2**.

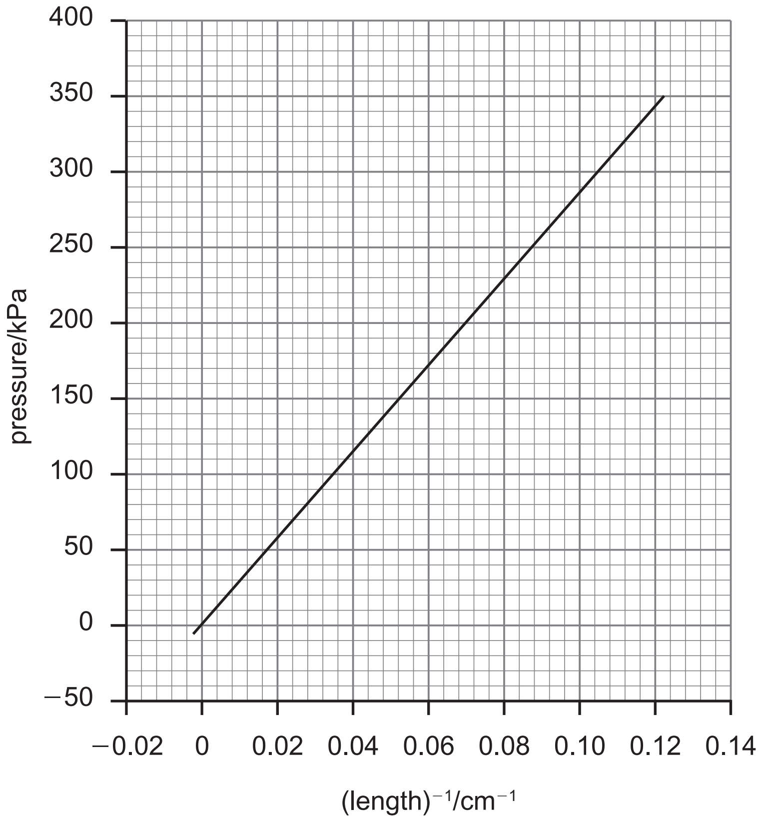

Fig. 2.2

(i) State the gas law which can be deduced from the graph in **Fig. 2.2**.

____

____ [1]

Examiner Only

Marks	Remark

Examiner Only	
Marks	Remark

(ii) Calculate the temperature of the gas sample used in the experiment to obtain the data plotted in **Fig. 2.2**. The sample was enclosed in a tube of cross-sectional area 1.54×10^{-4} m^2 and contained 0.0018 moles of the gas.

Temperature ____________________ [3]

Examiner Only	
Marks	Remark

3 The temperature of 500 g of water drops by 6.9 °C when placed in a fridge for 20 minutes. 350 g of water, at a temperature of 22 °C, is placed in the **same fridge** for 30 minutes. What is the final temperature of the water after 30 minutes? Assume the containers holding the water samples are identical and have no impact on the calculation. The specific heat capacity of water is 4190 J K^{-1} kg^{-1}.

Temperature = ___________________ °C [5]

4 The Langhorne Speedway, shown in **Fig. 4.1**, was a purpose built automobile racetrack near Langhorne, Pennsylvania, USA.

The track was a flat circular ring of length (circumference) 1.61 km.

Image removed - image showed an aerial photo of a flat circular race circuit

Fig. 4.1

(a) Calculate the average angular velocity of a 450 kg racing car that completes a 50 lap race in 36.3 minutes.

Angular velocity = ____________________ rad s^{-1} [2]

(b) Calculate the average centripetal force on the 450 kg racing car during the race.

Centripetal force = ____________________ N [3]

Examiner Only	
Marks	Remark

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(Questions continue overleaf)

5 The graphs in **Fig. 5.1** and **Fig. 5.2** describe the motion of the same object.

Examiner Only	
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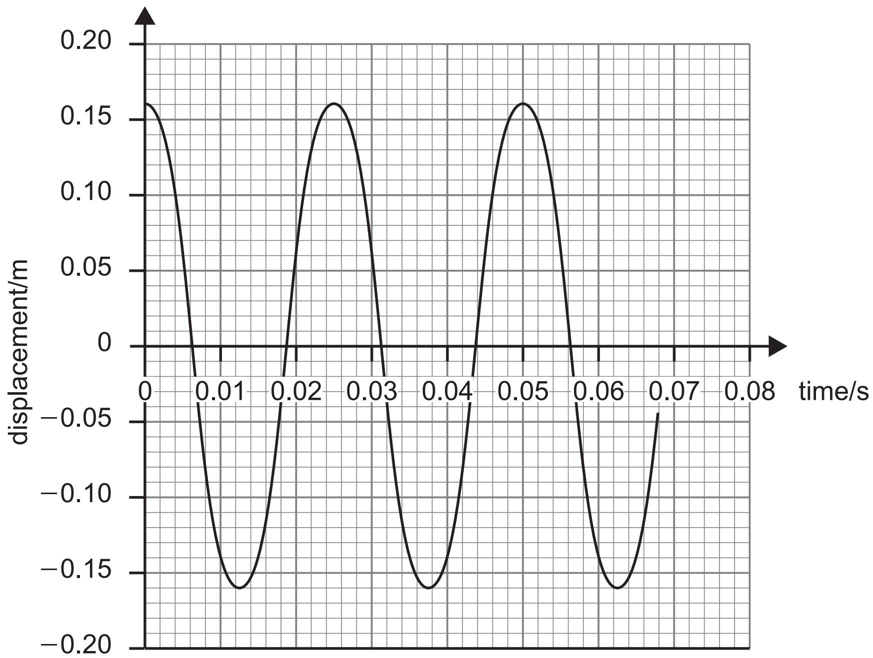

Fig. 5.1

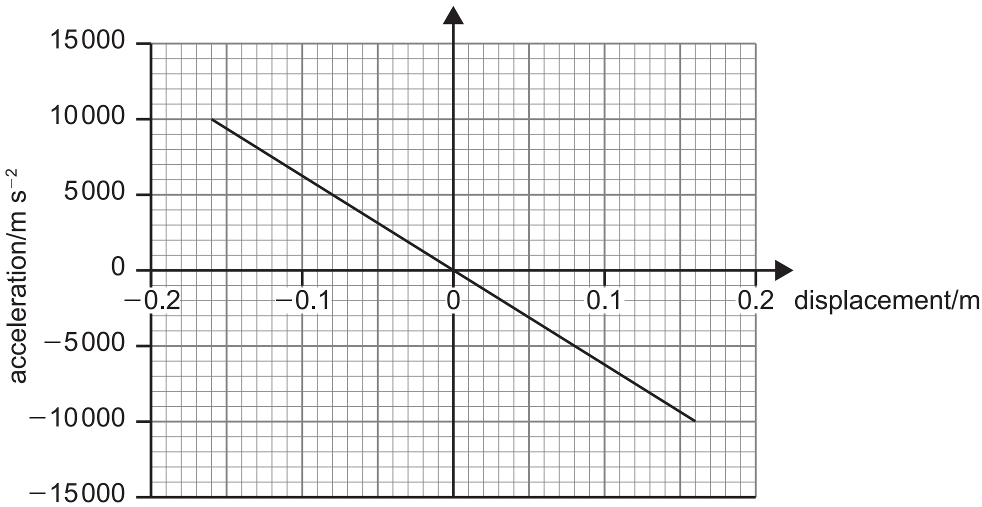

Fig. 5.2

Examiner Only	
Marks	Remark

(a) What type of motion is described by the two graphs opposite? Explain, in detail, how **Fig. 5.2** defines this type of motion.

____

____

____

____

____

____ [3]

(b) (i) The periodic time of the motion can be determined from both **Fig. 5.1** and **Fig. 5.2**. Confirm that these are the same.

Periodic time from **Fig. 5.1**	Periodic time from **Fig. 5.2**
Periodic time = ________ s	Periodic time = ________ s [4]

(ii) What other evidence exists to indicate that each graph describes the same motion?

____

____ [1]

6 In an experiment carried out over several months in 1909, Geiger and Marsden aimed a stream of alpha particles at a thin gold foil. The alpha particles were emitted by a radon **radioactive source**. By looking through the microscope part of the detector, Geiger and Marsden would observe the scintillations (flashes) caused by the alpha particles when they hit the zinc sulphide screen of the detector. The detector could be rotated a full 360° around the gold foil. They used apparatus similar to that shown in **Fig. 6.1**.

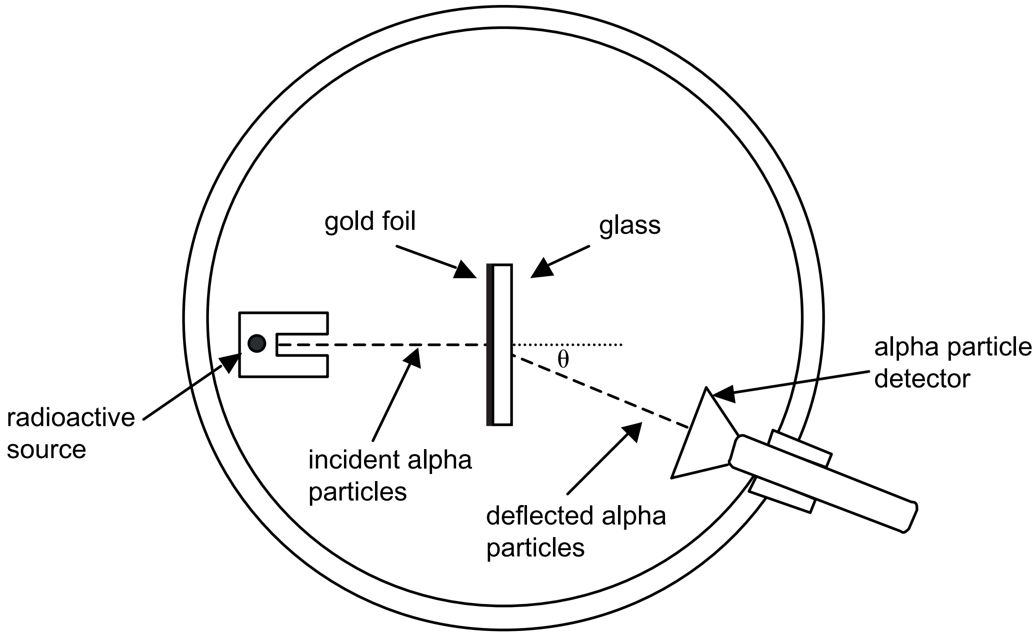

Fig. 6.1

(a) The gold foil had a thickness of 8.6×10^{-6} cm and was so thin that it had to be supported by draping it over a solid glass plate, see **Fig. 6.1**. The glass was chosen because it was **almost transparent** to alpha particles.

Table 6.1 contains data from the Geiger-Marsden α-scattering experiment. The data was collected over **51 hours**.

Table 6.1

Detector Angle θ/°	Mean number of scintillations per minute			
	Without foil	**With foil**	**Corrected for effect without foil**	**Corrected for decay**
60	0.3	69.2	68.9	101
75	0.0	28.6	28.6	41.9
105	0.6	10.6	10.0	14.6
120	3.8	10.3	6.5	9.5
135	2.6	8.3	5.7	8.4
150	0.2	4.9	4.7	6.9

Note. A detector angle of 0° corresponds to the alpha particles passing straight through the gold foil.

Examiner Only
Marks | Remark

(i) Explain the purpose of recording data in the columns headed "Without foil", "With foil" and "Corrected for effect without foil".

____

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____

____ [2]

(ii) Suggest a reason why it was impractical for Geiger and Marsden to record data for angles less than 60°.

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____ [1]

(iii) Given that the α-scattering data was collected over a 51 hour period, explain the final column "Corrected for decay".

____

____

____ [2]

(b) Explain how the data obtained from the alpha scattering experiment leads to the nuclear model of an atom.

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____ [3]

Examiner Only	
Marks	Remark

7 (a) (i) Explain the phrase "*the random nature of radioactive decay*".

____

____ [1]

(ii) What does the term *exponential decay* mean?

____

____ [1]

(b) (i) Describe a simple experiment which illustrates exponential decay and does not involve the actual use of a radioactive material.

1. List the apparatus used and the results that are taken.

____

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____ [2]

2. Describe the procedure for gathering data.

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____ [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

(ii) Explain how the results can be used to draw a graph to show that the modelled decay is exponential. The space below is provided for any graph you may choose to sketch in answering this question.

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____

____

____ [3]

(c) Strontium-89 decays by the emission of beta particles and has a half life of 51 days. Calculate the activity of a sample of strontium-89 after one day. Initially the sample contained 5.98×10^{25} atoms.

Activity = ____________________ Bq [3]

8 Induced fission of uranium-235 results in the reaction described in **Equation 8.1**.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{98}_{42}Mo + ^{136}_{54}Xe + 2^{1}_{0}n + Q \quad \textbf{Equation 8.1}$$

Symbol	Description	Rest mass/u
$^{235}_{92}U$	uranium nuclide	235.044
$^{98}_{42}Mo$	molybdenum nuclide	97.905
$^{136}_{54}Xe$	xenon nuclide	135.917
$^{1}_{0}n$	neutron	1.009
Q	quantity of energy released	not applicable

(a) Calculate the energy released, in joule, from the fission of a single uranium-235 nucleus in the reaction described in **Equation 8.1**.

Q = ____________________ J [4]

(b) Calculate the energy released from the fission of 1.00 kg of uranium-235.

Q = ____________________ J kg^{-1} [2]

Examiner Only

Marks	Remark

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(Questions continue overleaf)

In this question you will be assessed on the quality of your written communication. You are advised to answer in continuous prose.

Examiner Only	
Marks	Remark

9 The main components of a reactor capable of **controlled** uranium-235 fission are shown in **Fig. 9.1**.

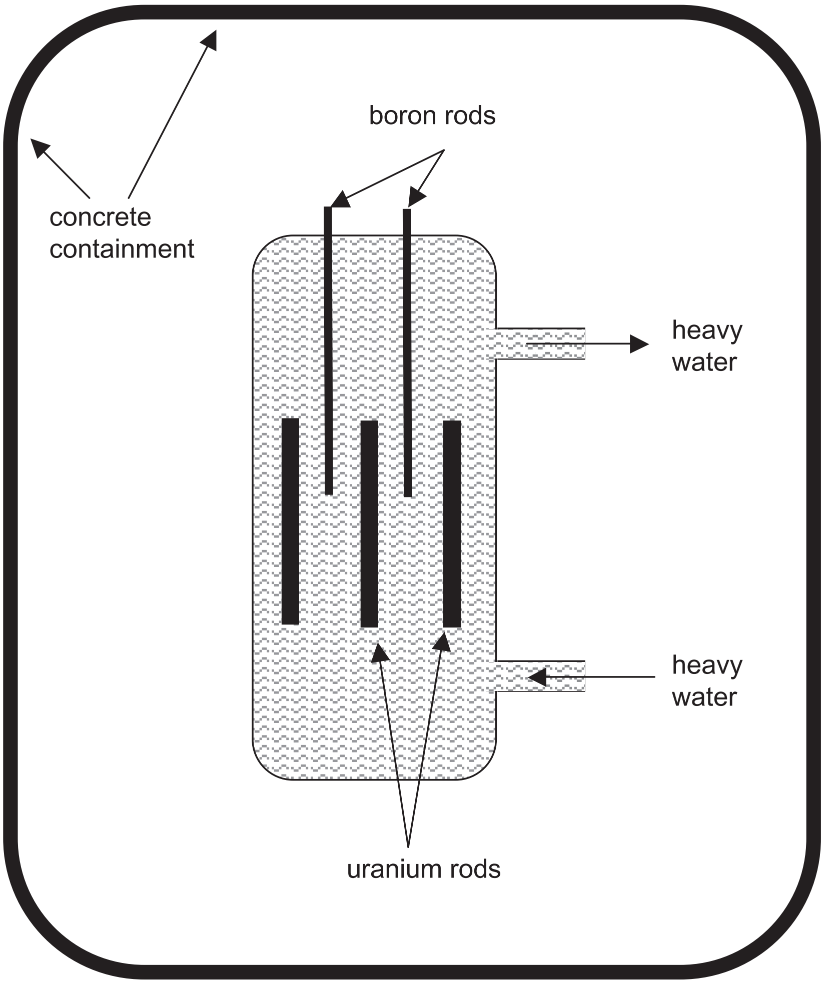

Fig. 9.1

(a) Name the function of the boron rods and explain why they have to be able to move up and down.

____

____

____

____ [2]

(b) Explain why the uranium fuel is inserted into the reactor in rods rather than as one single mass.

____

____

____

____ [1]

(c) The heavy water performs two functions within the reactor.

(i) One function is to act as a moderator. Explain why this is necessary.

____

____ [2]

(ii) Name the other function of the heavy water and explain why this is necessary.

____

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____ [1]

Quality of written communication [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

10 (a) (i) State and explain the conditions required for nuclear fusion.

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____ [2]

(ii) Outline **three** possible methods of plasma confinement.

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____ [3]

(b) Estimate the temperature of a high mass star when fusion is taking place if the mean kinetic energy per nuclide involved is 4.48×10^{-14} J.

Temperature ____________________ K [2]

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(Questions continue overleaf)

Data Analysis Question

Examiner Only	
Marks	Remark

This question contributes to the synoptic requirement of the specification. In your answer you will be expected to bring together and apply principles and concepts from different areas of physics, and to use the skills of physics in the particular situation described.

11 In a radioactive disintegration the original nucleus, called the parent, changes into another nucleus, called the daughter. The daughter may be radioactive and decay further giving rise to a decay chain or series. **Table 11.1** provides information about the Thorium series α-emitters.

Table 11.1

Parent nuclide symbol	Range in air/mm	Kinetic energy of emitted α/MeV	Half-life of nuclide	λ/s^{-1}
$^{232}_{90}Th$	29.0	3.98	1.39×10^{10} y	1.58×10^{-18}
$^{228}_{90}Th$	40.2	5.42	1.9 y	1.16×10^{-8}
$^{224}_{88}Ra$	43.5	5.68	3.64 d	2.20×10^{-6}
$^{220}_{86}Rn$	50.6	6.28	54.5 s	1.27×10^{-2}
$^{216}_{84}Po$	56.8	6.77	0.16 s	4.33
$^{212}_{84}Po$	86.2	8.77	3×10^{-7} s	2.31×10^{6}

Where y = years, d = days, s = seconds

(a) **Equation 11.1** shows the theoretical relationship between the range, R, of the α-particles and their velocity, v.

$$R = av^3 \qquad \textbf{Equation 11.1}$$

Use the data for $^{216}_{84}Po$ in **Table 11.1** to determine a value for constant a, in S.I. units.
Note, the α-particle has a mass of 6.64×10^{-27} kg.

Constant a = ___________________ $m^{-2}\,s^3$ [4]

(b) An α-particle loses energy through ionisation of the particles of the material through which it is moving. On the axes of **Fig. 11.1** are plotted points to show the manner in which an α-particle from a polonium-210 nucleus loses its energy moving through air.

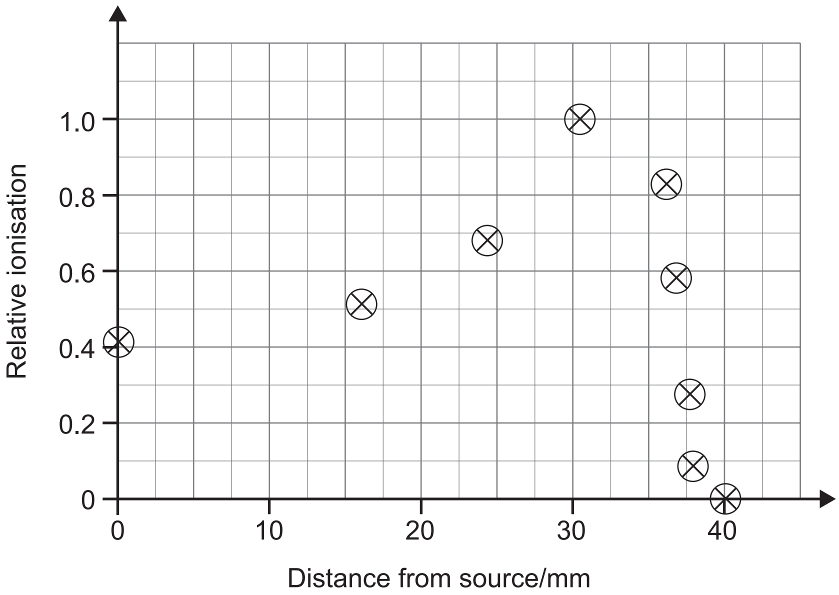

Fig. 11.1

(i) Draw a best fit curved line through the points of **Fig. 11.1**. [1]

(ii) The "range" of the α-particle is found by extrapolating the almost vertical part of the curve to zero relative ionisation. Determine the range of these α-particles in air.

Range = ____________________ mm [1]

(iii) Describe how relative ionisation varies with α-particle **velocity**.

____

____ [1]

Examiner Only	
Marks	Remark

(c) **Fig. 11.2** is a graph drawn from the data for the Thorium series of α-particle emitters given in **Table 11.1**. The linear relationship between the plotted quantities is called the Geiger–Nuttall equation. $T_{\frac{1}{2}}$ is the half-life (in seconds) of the nuclide and Q is the kinetic energy (in MeV) with which the α-particle is emitted from the nucleus and Z is the atomic number of the **daughter** nucleus.

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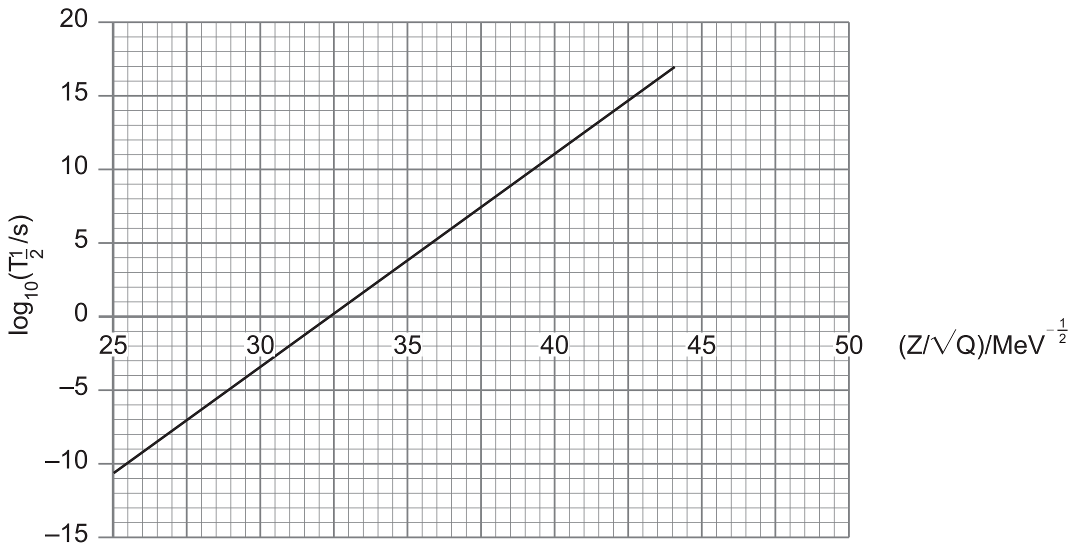

Fig. 11.2

(i) Show that the Geiger–Nuttall equation from the specific linear relationship shown in **Fig. 11.2** is:

$$\log_{10}(T_{\frac{1}{2}}) = \frac{1.4\,Z}{\sqrt{Q}} - 45$$

[4]

(ii) By calculation, determine whether this Geiger–Nuttall equation is consistent to within 5% for an α-emitter from the Radium series. **Table 11.2** provides the necessary data on uranium-238, part of the Radium series.

Table 11.2

Parent Nuclide symbol	Energy/MeV	Half-life/s
$^{238}_{92}U$	4.27	1.41×10^{17}

N.B. Z, in the Geiger–Nuttall equation, is the atomic number of the **daughter** nuclide.

[4]

THIS IS THE END OF THE QUESTION PAPER

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Marks	Remark

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GCE Physics

Data and Formulae Sheet for A2 1 and A2 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{F}^{-1}\ \text{m}\right)$
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
(unified) atomic mass unit	1 u = 1.66×10^{-27} kg
mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall on the Earth's surface	$g = 9.81$ m s^{-2}
electron volt	1 eV = 1.60×10^{-19} J

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The following equations may be useful in answering some of the questions in the examination:

Mechanics

Conservation of energy	$\frac{1}{2} mv^2 - \frac{1}{2} mu^2 = Fs$ for a constant force
Hooke's Law	$F = kx$ (spring constant k)

Simple harmonic motion

Displacement	$x = A \cos \omega t$

Sound

Sound intensity level/dB	$= 10 \lg_{10} \frac{I}{I_0}$

Waves

Two-source interference	$\lambda = \frac{ay}{d}$

Thermal physics

Average kinetic energy of a molecule	$\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$
Kinetic theory	$pV = \frac{1}{3} Nm \langle c^2 \rangle$
Thermal energy	$Q = mc\Delta\theta$

Capacitors

Capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
Capacitors in parallel	$C = C_1 + C_2 + C_3$
Time constant	$\tau = RC$

Light

Lens formula $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Magnification $m = \frac{v}{u}$

Electricity

Terminal potential difference $V = E - Ir$ (e.m.f. E; Internal Resistance r)

Potential divider $V_{out} = \frac{R_1 V_{in}}{R_1 + R_2}$

Particles and photons

Radioactive decay $A = \lambda N$

$A = A_0 e^{-\lambda t}$

Half-life $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

de Broglie equation $\lambda = \frac{h}{p}$

The nucleus

Nuclear radius $r = r_0 A^{\frac{1}{3}}$

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