

AQA A-LEVEL PHYSICS

PHYSICS



EXAM QUESTION PACK

UNIT 5 SECTION A OLD SPECIFICATION PAPERS

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	



General Certificate of Education
Advanced Level Examination
June 2015

Physics A

PHYA5/1R

Unit 5 Nuclear and Thermal Physics Section A

Thursday 18 June 2015 9.00 am to 10.45 am

For this paper you must have:

- a calculator
- a pencil and a ruler
- a question paper/answer book for Section B (enclosed).

Time allowed

- The total time for both sections of this paper is 1 hour 45 minutes.
You are advised to spend approximately 55 minutes on this section.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this section is 40.
- You are expected to use a calculator, where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert in Section B.
- You will be marked on your ability to:
 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.



J U N 1 5 P H Y A 5 1 R 0 1

G/ME/Jun15/PHYA5/1R/E1

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PHYA5/1R

Section A

The maximum mark for this section is 40.
You are advised to spend approximately 55 minutes on this section.

- 1 (a)** Which ionizing radiation produces the greatest number of ion pairs per mm in air?
Tick (✓) the correct answer.

[1 mark]

α particles	
β particles	
γ rays	
X-rays	

- 1 (b) (i)** Complete **Table 1** below showing the typical maximum range in air for α and β particles.
[2 marks]

Table 1

Type of radiation	Typical range in air / m
α	
β	

- 1 (b) (ii)** γ rays have a range of at least 1 km in air.
However, a γ ray detector placed 0.5 m from a γ ray source detects a noticeably smaller count-rate as it is moved a few centimetres further away from the source.

Explain this observation.

[1 mark]

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- 1 (c)** Following an accident, a room is contaminated with dust containing americium which is an α -emitter.

Explain the most hazardous aspect of the presence of this dust to an unprotected human entering the room.

[2 marks]

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6

Turn over for the next question

Turn over ►



- 2 (a)** Scattering experiments are used to investigate the nuclei of gold atoms. In one experiment, alpha particles, all of the same energy (monoenergetic), are incident on a foil made from a single isotope of gold.

- 2 (a) (i)** State the main interaction when an alpha particle is scattered by a gold nucleus.

[1 mark]

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- 2 (a) (ii)** The gold foil is replaced with another foil of the same size made from a mixture of isotopes of gold. Nothing else in the experiment is changed.

Explain whether or not the scattering distribution of the monoenergetic alpha particles remains the same.

[1 mark]

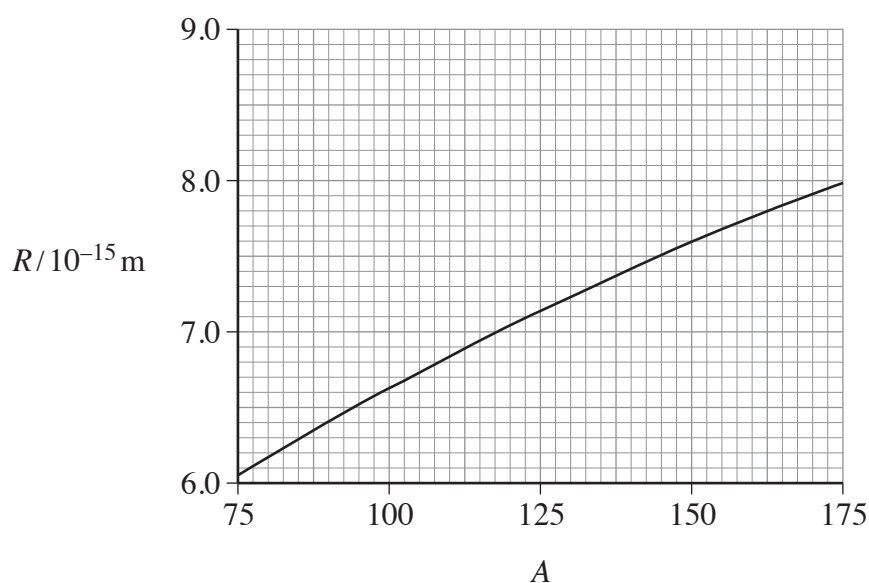
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- 2 (b)** Data from alpha-particle scattering experiments using elements other than gold allow scientists to relate the radius R , of a nucleus, to its nucleon number, A . **Figure 1** shows the relationship obtained from the data in a graphical form, which obeys the relationship $R = r_0 A^{\frac{1}{3}}$.

Figure 1



2 (b) (i) Use information from **Figure 1** to show that r_0 is about 1.4×10^{-15} m.

[1 mark]

2 (b) (ii) Show that the radius of a ${}^{51}_{23}\text{V}$ nucleus is about 5×10^{-15} m.

[2 marks]

2 (c) Calculate the density of a ${}^{51}_{23}\text{V}$ nucleus.

State an appropriate unit for your answer.

[3 marks]

density unit



- 3** A rod made from uranium-238 ($^{238}_{92}\text{U}$) is placed in the core of a nuclear reactor where it absorbs free neutrons.

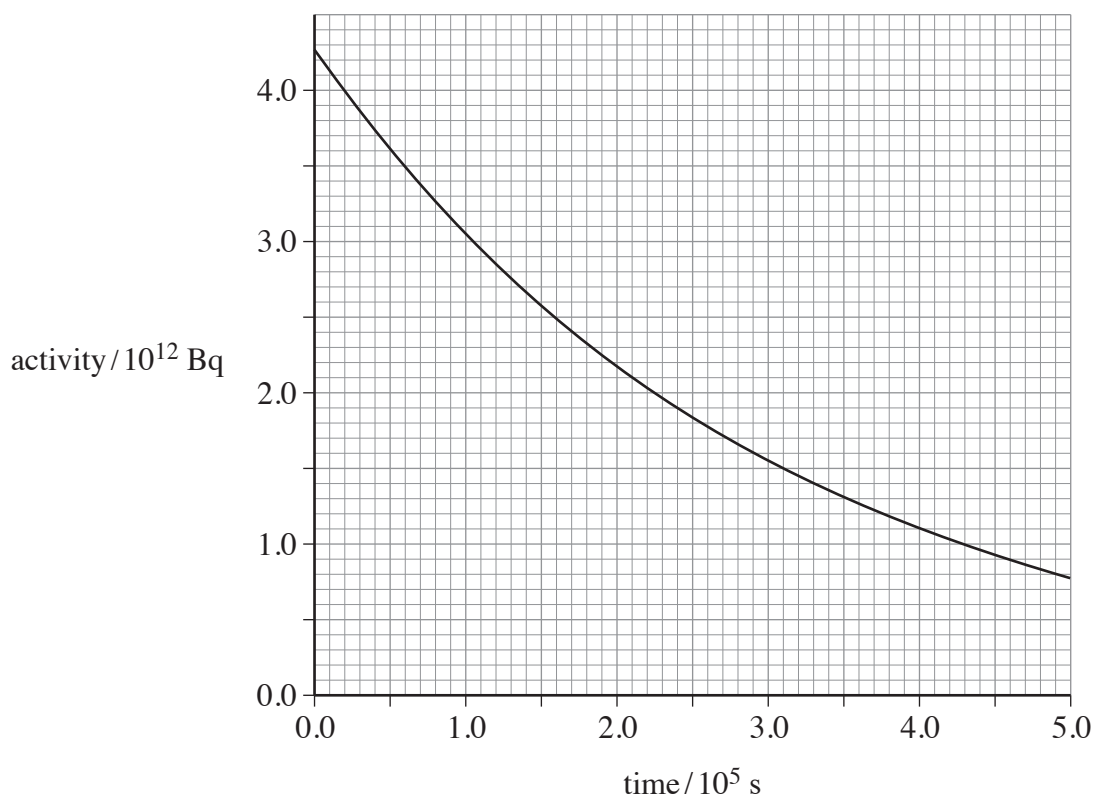
When a nucleus of uranium-238 absorbs a neutron it becomes unstable and decays to neptunium-239 ($^{239}_{93}\text{Np}$), which in turn decays to plutonium-239 ($^{239}_{94}\text{Pu}$).

- 3 (a)** Write down the nuclear equation that represents the decay of neptunium-239 into plutonium-239.

[2 marks]

- 3 (b)** A sample of the rod is removed from the core and its radiation is monitored from time $t = 0$ s.
The variation of the activity with time is shown in **Figure 2**.

Figure 2



3 (b) (i) Show that the decay constant of the sample is about $3.4 \times 10^{-6} \text{ s}^{-1}$.

[2 marks]

3 (b) (ii) Assume that the activity shown in **Figure 2** comes only from the decay of neptunium.

Estimate the number of neptunium nuclei present in the sample at
time $t = 5.0 \times 10^5 \text{ s}$.

[1 mark]

number of nuclei

Question 3 continues on the next page

Turn over ►



- 3 (c) (i)** A chain reaction is maintained in the core of a thermal nuclear reactor that is operating normally.

Explain what is meant by a chain reaction, naming the materials and particles involved.

[2 marks]

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- 3 (c) (ii)** Explain the purpose of a moderator in a thermal nuclear reactor.

[2 marks]

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- 3 (c) (iii)** Substantial shielding around the core protects nearby workers from the most hazardous radiations. Radiation from the core includes α and β particles, γ rays, X-rays, neutrons and neutrinos.

Explain why the shielding becomes radioactive.

[2 marks]

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- 4 (a)** Lead has a specific heat capacity of $130 \text{ J kg}^{-1} \text{ K}^{-1}$.

Explain what is meant by this statement.

[1 mark]

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- 4 (b)** Lead of mass 0.75 kg is heated from 21°C to its melting point and continues to be heated until it has all melted.

Calculate how much energy is supplied to the lead.

Give your answer to an appropriate number of significant figures.

melting point of lead = 327.5°C

specific latent heat of fusion of lead = $23\,000 \text{ J kg}^{-1}$

[3 marks]

energy supplied J

4

Turn over ►



5 (a)

The concept of an absolute zero of temperature may be explained by reference to the behaviour of a gas.

Discuss **one** experiment that can be performed using a gas which would enable you to explain absolute zero and determine its value.

It is not necessary to give full details of the apparatus. Your answer should:

- include the quantities that are kept constant
- identify the measurements to be taken
- explain how the results may be used to find absolute zero
- justify why the value obtained is absolute zero.

The quality of your written communication will be assessed in your answer.

[6 marks]

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Question 5 continues on the next page

Turn over ►



- 5 (b) (i)** State **two** assumptions about the **movement** of molecules that are used when deriving the equation of state, $pV = \frac{1}{3} N m (c_{\text{rms}})^2$ for an ideal gas.

[2 marks]

- 1
-
- 2
-

- 5 (b) (ii)** Three molecules move at the speeds shown in **Table 2**.

Table 2

molecule	speed / m s ⁻¹
1	2000
2	3000
3	7000

Calculate their mean square speed.

[1 mark]

mean square speed m² s⁻²



- 5 (c)** The average molecular kinetic energy of an ideal gas is 6.6×10^{-21} J.
Calculate the temperature of the gas.

[2 marks]

temperature K

11

END OF SECTION A

Turn over ►



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A-level Physics

PHYA5/1R – Nuclear and Thermal Physics
Mark scheme

2450
June 2015

Version 1: Final mark scheme

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this mark scheme are available from aqa.org.uk

Question	Answers		Additional Comments/Guidance	Mark	ID details						
1 (a)	A α particles ✓		[auto mark question]	1							
1 (b)(i)	<table><tr><th>type of radiation</th><th>Typical range in air/m</th></tr><tr><td>α</td><td>0.04 ✓</td></tr><tr><td>β</td><td>0.40 ✓</td></tr></table>	type of radiation	Typical range in air/m	α	0.04 ✓	β	0.40 ✓		allow students to use their own distance units in the table α allow 0.03 $\rightarrow$ 0.07 m β allow 0.20 $\rightarrow$ 3.0 m If a range is given in the table use the larger value. A specific number is required eg not just a few cm.	2	
type of radiation	Typical range in air/m										
α	0.04 ✓										
β	0.40 ✓										
1 b)(ii)	reference to the <u>inverse</u> square law of (γ radiation) or reference to lowering of the solid angle (subtended by the detector as it moves away) or radiation is spread out (over a larger surface area as the detector is moved away)✓		(owtte) Ignore any references to other types of radiation. Any contradiction loses the mark. For example, follows inverse square law so intensity falls exponentially.	1							
1(c)	dust may be <u>ingested/taken into the body/breathed in</u> ✓ causing (molecules in human tissue/cells) to be <u>made cancerous / killed / damaged by ionisation</u> ✓		first mark for ingestion not just on the body second mark for idea of <u>damage</u> from <u>ionisation</u>	2							
Total				6							

Question	Answers	Additional Comments/Guidance	Mark	ID details
2 (a)(i)	electromagnetic/electrostatic/Coulomb (repulsion between the alpha particles and the nuclei) ✓	The interaction must be named not just described.	1	
2 (a)(ii)	the scattering distribution remains the same (because the alpha particles interact with a nucleus) whose charge/proton number/atomic number remains the same or the (repulsive) force remains the same Or the scattering distribution changes/becomes less distinct because there is a mixture of nuclear <u>masses</u> (which gives a mixture of nuclear recoils) ✓ (owtte)	The mark requires a described distribution <u>and the reason</u> for it. A reference must be made to mass and not density or size.	1	
2 (b)(i)	use of graph to find r_0 eg $r_0 = 6.0 \times 10^{-15} / 75^{1/3}$ ✓ (or $8.0 \times 10^{-15} / 175^{1/3}$) ($r_0 = 1.43 \times 10^{-15}$ m)	Substitution and calculation must be shown. Condone a gradient calculation on <u>R against $A^{1/3}$</u> graph (not graph of Fig 1) as $R \propto A^{1/3}$	1	
2 (b)(ii) Escalate if clip shows ${}_{13}^{27}\text{Al}$ in the question giving $R \approx 4 \times 10^{-15}$ m.				
2 (b)(ii)	(using $R = r_0 A^{1/3}$) $R = 1.43 \times 10^{-15} \times 51^{1/3}$ ✓ $R = 5.3 \times 10^{-15}$ (m) ✓ ($R = 5.2 \times 10^{-15}$ m from $r_0 = 1.4 \times 10^{-15}$ m)	first mark for working second mark for evaluation which must be 2 or more sig figs allow CE from b(i) $R = 3.71 \times$ b(i) Possible escalation	2	
2 (c) Escalate if clip shows ${}_{13}^{27}\text{Al}$ in the question and/or the use of 27 in the working.				
2 (c)	density = mass / volume $m = 51 \times 1.67 \times 10^{-27}$ ($= 8.5 \times 10^{-26}$ kg) $v = 4/3\pi(5.3 \times 10^{-15})^3$ ($6.2(4) \times 10^{-43}$ m ³) Or density = $A \times u / 4/3\pi(r_0 A^{1/3})^3$	give the first mark for substitution of data into the top line or bottom line of the calculation of density. In the second alternative the mark for the substitution is only given if the working equation is given as well. $51 \times 1.67 \times 10^{-27}$ would gain a mark on its own but 1.66×10^{-27}	3	

	$= u / 4/3\pi(r_0)^3$ top line = 1.66×10^{-27} bottom line = $4/3\pi(1.43 \times 10^{-15})^3$ ✓ for one substitution density = 1.4×10^{17} ✓ (1.37×10^{17}) kg m^{-3} ✓	would need $u / 4/3\pi(r_0)^3$ as well to gain the mark. Expect a large spread of possible answers. For example If $R = 5 \times 10^{-15}$ $V = 5.24 \times 10^{-43}$ and density = 1.63×10^{17} Possible escalation		
			8	

Question	Answers	Additional Comments/Guidance	Mark	ID details
3(a)	${}_{93}^{239}\text{Np} \rightarrow {}_{94}^{239}\text{Pu} + {}_{(-1)}^{(0)}\beta^{-} + {}_{(0)}^{(0)}\bar{\nu}$ ✓✓	First mark for one anti-neutrino or one beta minus particle in any form eg. e^{-} . If subscript and superscripts are given for these they must be correct but ignore the type of neutrino if indicated. The second mark is for both particles and the rest of the equation. Ignore the full sequence if it is shown but the Np to Pu must be given separately for the mark.	2	
3(b)(i)	$T_{1/2} 2.0 \rightarrow 2.1 \times 10^5 \text{ s}$ ✓ then substitute and calculate $\lambda = \ln 2 / T_{1/2}$ ✓ Or (substitute two points from the graph into $A = A_0 e^{-\lambda t}$) e.g. 0.77×10^{12} $= 4.25 \times 10^{12} \exp(-\lambda \times 5 \times 10^5)$ ✓ then make λ the subject and	$T_{1/2}$ may be determined from graph not starting at zero time. Look for the correct power of 10 in the half-life – possible AE. Allow the rare alternative of using the time constant of the decay $A = A_0 \exp(-t/t_{ic})$ from graph $t_{ic} = 2.9 \rightarrow 3.1 \times 10^5 \text{ s}$ ✓ $\lambda = 1/t_{ic} = 3.4 \times 10^{-6} \text{ s}^{-1}$ ✓	2	

	calculate ✓ (the rearrangement looks like $\lambda = [\ln (A_0 / A)] / t$ or $\lambda = - [\ln (A / A_0)] / t$) both alternatives give $\lambda = 3.3 \rightarrow 3.5 \times 10^{-6} \text{ s}^{-1}$ ✓	No CE is allowed within this question. For reference $T_{1/2} = 2.0 \times 10^5 \text{ s}$ gives $\lambda = 3.5 \times 10^{-6} \text{ s}^{-1}$ and $T_{1/2} = 2.1 \times 10^5 \text{ s}$ gives $\lambda = 3.3 \times 10^{-6} \text{ s}^{-1}$		
3(b)(ii)	(using $A = N\lambda$ $N = 0.77 \times 10^{12} / 3.4 \times 10^{-6}$ $= 2.2(6) \times 10^{17}$) allow $2.2 \rightarrow 2.4 \times 10^{17}$ nuclei ✓	A possible route is find $N_0 = A_0/\lambda$ then use $N = N_0 e^{-\lambda t}$ condone lone answer	1	
3 (c)(i)	<u>uranium</u> (– 235 captures) a <u>neutron</u> (and splits into 2 smaller nuclei/fission fragments) <u>releasing more neutrons</u> ✓ (at least one of) <u>these neutrons</u> go on to cause further/more <u>splitting/fissioning</u> (of uranium–235) ✓	first mark for uranium + neutron gives more neutrons Ignore which isotope of uranium is used. second mark for released neutron causes more fission The word ‘reaction’ may replace ‘fission’ here provided ‘fission/splitting of uranium’ is given somewhere in the answer.	2	
3 (c)(ii) Escalate if clip shows critical mass in the question.				
3 (c)(ii)	the moderator slows down/reduces the kinetic energy of <u>neutrons</u> ✓ so neutrons are absorbed/react/fission (efficiently) by the <u>uranium/fuel</u> ✓	owtte Possible escalation	2	
3 (c)(iii)	<u>neutrons</u> are absorbed/collide with (by the nuclei in the shielding) ✓ converting the nuclei/atoms (of the shielding) into unstable isotopes (owtte) ✓	Second mark is only given if neutrons appear somewhere in the answer. No neutrons = no marks making it neutron rich implies making them unstable.	2	
Total			11	

Question	Answers	Additional Comments/Guidance	Mark	ID details
4 (a)	(it takes) 130 J/this energy to raise (the temperature of) a mass of 1 kg (of lead) by 1 K / 1 °C (without changing its state) ✓	1 kg can be replaced with unit mass marks for 130J or energy +1 kg or unit mass +1 K or 1 °C Condone the use of 1 °K	1	
4 (b)	(using $Q = mc\Delta T + ml$) = $0.75 \times 130 \times (327.5 - 21) + 0.75 \times 23000$ ✓ (= 29884 + 17250) = 47134 ✓ = 4.7×10^4 (J) ✓	For the first mark the two terms may appear separately ie they do not have to be added. Marks for substitution + answer + 2 sig figs (that can stand alone)	3	
Total			4	

Question	Answers	Additional Comments/Guidance	Mark	ID details
5 (a)	See below - QWC		6	

The mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC).			
Descriptor	Mark		
High Level – Good to Excellent An experiment with results and interpretation must be given leading to the measurement of absolute zero. The student refers to 5 or 6 points given below. However each individual point must stand alone and be clear. <i>The information presented as a whole should be well organised using appropriate specialist vocabulary. There should only be one or two spelling or grammatical errors for this mark.</i>	5-6	6 clear points = 6 marks 5 clear points = 5 marks	
Intermediate Level – Modest to Adequate An experiment must be given and appropriate measurements must be suggested. For 3 marks the type of results expected must be given. 4 marks can only be obtained if the method of obtaining absolute zero is given. <i>The grammar and spelling may have a few shortcomings but the ideas must be clear.</i>	3-4	4 clear points = 4 marks 3 clear points = 3 marks	
Low Level – Poor to Limited One mark may be given for any of the six points given below. For 2 marks an experiment must be chosen and some appropriate results suggested even if the details are vague. Any 2 of the six points can be given to get the marks. <i>There may be many grammatical and spelling errors and the information may be poorly organised.</i>	1 - 2	2 clear points = 2 marks Any one point = 1 mark	
The description expected in a competent answer should include: 1. Constant mass of gas (may come from the experiment if it is clear that the gas is trapped) <u>and</u> constant volume (or constant pressure). 2. Record pressure (or volume) for a range of temperatures. (the experiment must involve changing the temperature with pressure or volume being the dependent variable) 3. How the temperature is maintained/changed/controlled. (The gas must be heated uniformly by a temperature bath or oven – so not an electric fire or lamp) 4. Describe or show a graph of pressure against temperature (or volume against temperature) that is linear. The linear relationship may come from a diagram/graph or a reference to the Pressure Law or Charles' Law (line of best fit is continued on implies a linear graph)		for (point 1) amount/quantity/moles of gas is acceptable for (point 2) no specific details of the apparatus are needed. Also the temperature recording may not be explicitly stated eg. record the pressure at different temperatures is condoned for (points 4 and 5) the graphs referred to can use a different variable to pressure or volume but its relationship to V or P <u>must</u> be explicit	

5. Use the results in a graph of pressure against temperature (or volume against temperature) which can be extrapolated to lower temperatures which has zero pressure (or volume) at absolute zero, <u>which is at 0 K or -273 °C</u> (a reference to crossing the temperature axis implies zero pressure or volume) 6. Absolute zero is obtained using any gas (provided it is ideal or not at high pressures or close to liquification) Or Absolute temperature is the temperature at which the volume (or pressure or mean kinetic energy of molecules) is zero./or when the particles are not moving Discount any point that are vague or unclear		in (point 5) the graph can be described or drawn (second part of point 6) must be stated not just implied from a graph

Question	Answers	Additional Comments/Guidance	Mark	ID details
5 (b)(i)	- The motion of molecules is random. - Collisions between molecules (or molecules and the wall of the container) are elastic. - The time taken for a collision is negligible (compared to the time between collisions) - Newtonian mechanics apply (or the motion is non-relativistic). - The effect of gravity is ignored or molecules move in straight lines (at constant speed) between collisions. ✓✓ any two	If more than 2 answers are given each wrong statement cancels a correct mark.	2	
5 (b)(ii) Escalate if the numbers used are 4000, 5000 and 6000 giving 25666666 or similar.				
5 (b)(ii)	mean square speed $(= (2000^2 + 3000^2 + 7000^2) / 3 = 20.7 \times 10^6)$ $= 2.1 \times 10^7 \quad (\text{m}^2 \text{s}^{-2})$	common correct answers 20.7×10^6 21×10^6 2.07×10^7 2.1×10^7 20 700 000 21 000 000 Possible escalation	1	

5 (c) Escalate if the question and answer line requires a volume instead of a temperature.

5 (c)	(using $\text{meanKE} = 3RT/2N_A$) $T = 2N_A \times \text{meanKE} / 3R$ $= 2 \times 6.02 \times 10^{23} \times 6.6 \times 10^{-21} / 3 \times 8.31 \checkmark$ $= 320 \text{ (K)} \checkmark (318.8 \text{ K})$ Or (meanKE = $3kT/2$) $T = 2 \times \text{meanKE} / 3k$ $= 2 \times 6.6 \times 10^{-21} / 3 \times 1.38 \times 10^{-23} \checkmark$ $= 320 \text{ (K)} \checkmark (318.8 \text{ K})$	first mark for substitution into an equation second mark for answer Possible escalation Answer only can gain 2 marks	2	
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Total			11	
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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										



General Certificate of Education
Advanced Level Examination
June 2014

Physics A

PHYA5/1

Unit 5 Nuclear and Thermal Physics Section A

Thursday 19 June 2014 9.00 am to 10.45 am

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- a calculator
- a ruler
- a question paper/answer book for Section B (enclosed).

Time allowed

- The total time for both sections of this paper is 1 hour 45 minutes.
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 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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5	
TOTAL	



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WMP/Jun14/PHYA5/1/E5

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PHYA5/1

Section A

The maximum mark for this section is 40.
You are advised to spend approximately 55 minutes on this section.

- 1 (a)** State what is meant by the binding energy of a nucleus.

[2 marks]

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- 1 (b) (i)** When a ${}^{235}_{92}\text{U}$ nucleus absorbs a slow-moving neutron and undergoes fission one possible pair of fission fragments is technetium ${}^{112}_{43}\text{Tc}$ and indium ${}^{122}_{49}\text{In}$. Complete the following equation to represent this fission process.

[1 mark]



- 1 (b) (ii)** Calculate the energy released, in MeV, when a single ${}^{235}_{92}\text{U}$ nucleus undergoes fission in this way.

binding energy per nucleon of ${}^{235}_{92}\text{U} = 7.59 \text{ MeV}$

binding energy per nucleon of ${}^{112}_{43}\text{Tc} = 8.36 \text{ MeV}$

binding energy per nucleon of ${}^{122}_{49}\text{In} = 8.51 \text{ MeV}$

[3 marks]

energy released MeV



1 (b) (iii) Calculate the loss of mass when a ${}_{92}^{235}\text{U}$ nucleus undergoes fission in this way.

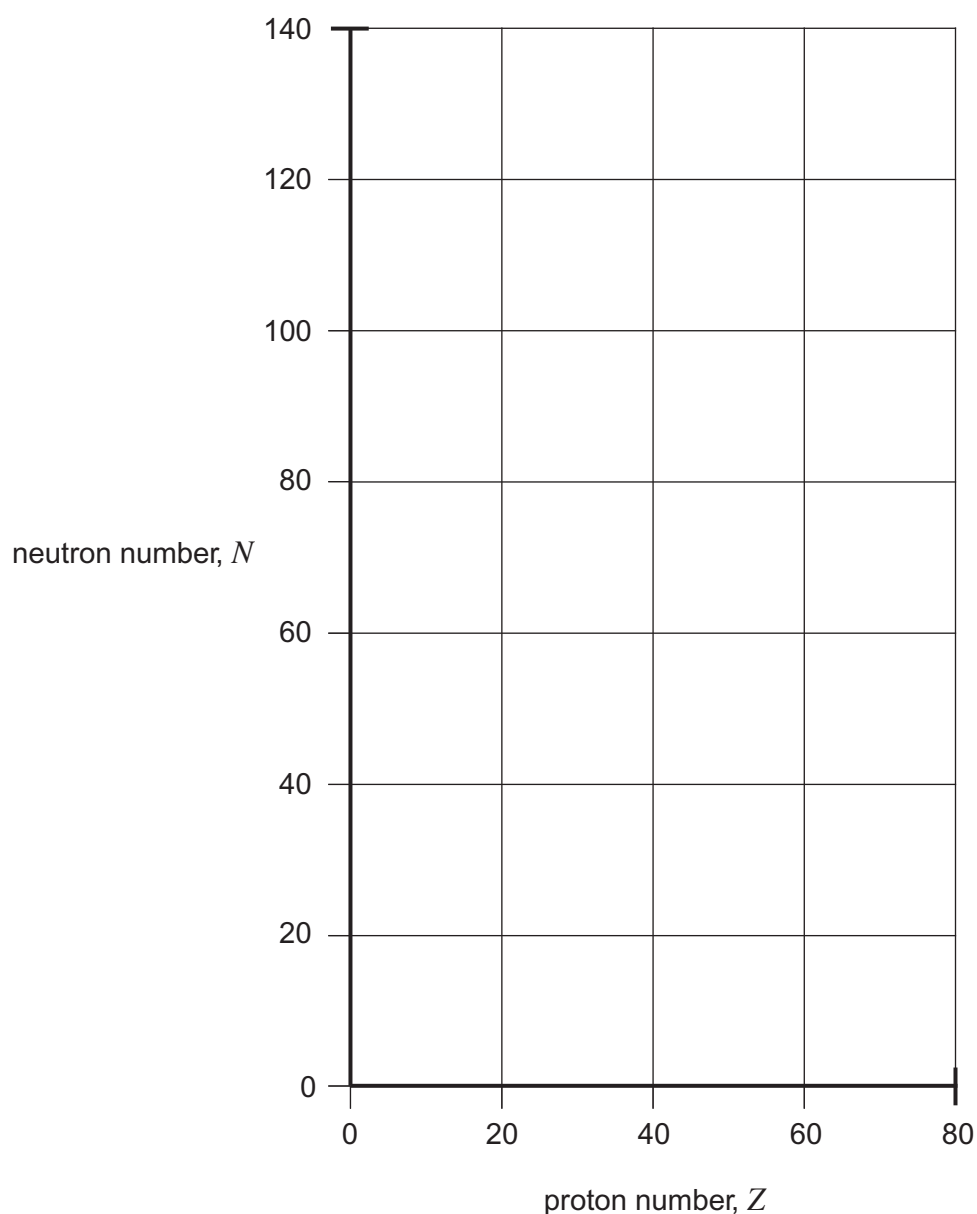
[2 marks]

loss of mass kg

1 (c) (i) On **Figure 1** sketch a graph of neutron number, N , against proton number, Z , for stable nuclei.

[1 mark]

Figure 1



Turn over ►



- 1 (c) (ii)** With reference to **Figure 1**, explain why fission fragments are unstable and explain what type of radiation they are likely to emit initially.

[3 marks]

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12



2 The carbon content of living trees includes a small proportion of carbon-14, which is a radioactive isotope. After a tree dies, the proportion of carbon-14 in it decreases due to radioactive decay.

2 (a) (i) The half-life of carbon-14 is 5740 years.
Calculate the radioactive decay constant in yr^{-1} of carbon-14.

[1 mark]

decay constant yr^{-1}

2 (a) (ii) A piece of wood taken from an axe handle found on an archaeological site has 0.375 times as many carbon-14 atoms as an equal mass of living wood.
Calculate the age of the axe handle in years.

[3 marks]

age yr

2 (b) Suggest why the method of carbon dating is likely to be unreliable if a sample is:

[2 marks]

2 (b) (i) less than 200 years old,

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2 (b) (ii) more than 60 000 years old.

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3 (a) Define the Avogadro constant.

[1 mark]

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3 (b) (i) Calculate the mean kinetic energy of krypton atoms in a sample of gas at a temperature of 22 °C.

[1 mark]

mean kinetic energy J

3 (b) (ii) Calculate the mean-square speed, $(c_{\text{rms}})^2$, of krypton atoms in a sample of gas at a temperature of 22 °C.

State an appropriate unit for your answer.

mass of 1 mole of krypton = 0.084 kg

[3 marks]

mean-square speed..... unit



- 3 (c)** A sample of gas consists of a mixture of krypton and argon atoms. The mass of a krypton atom is greater than that of an argon atom. State and explain how the mean-square speed of krypton atoms in the gas compares with that of the argon atoms at the same temperature.

[2 marks]

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7

Turn over for the next question

Turn over ►



- 4 (a) Define the specific latent heat of vaporisation of water.

[2 marks]

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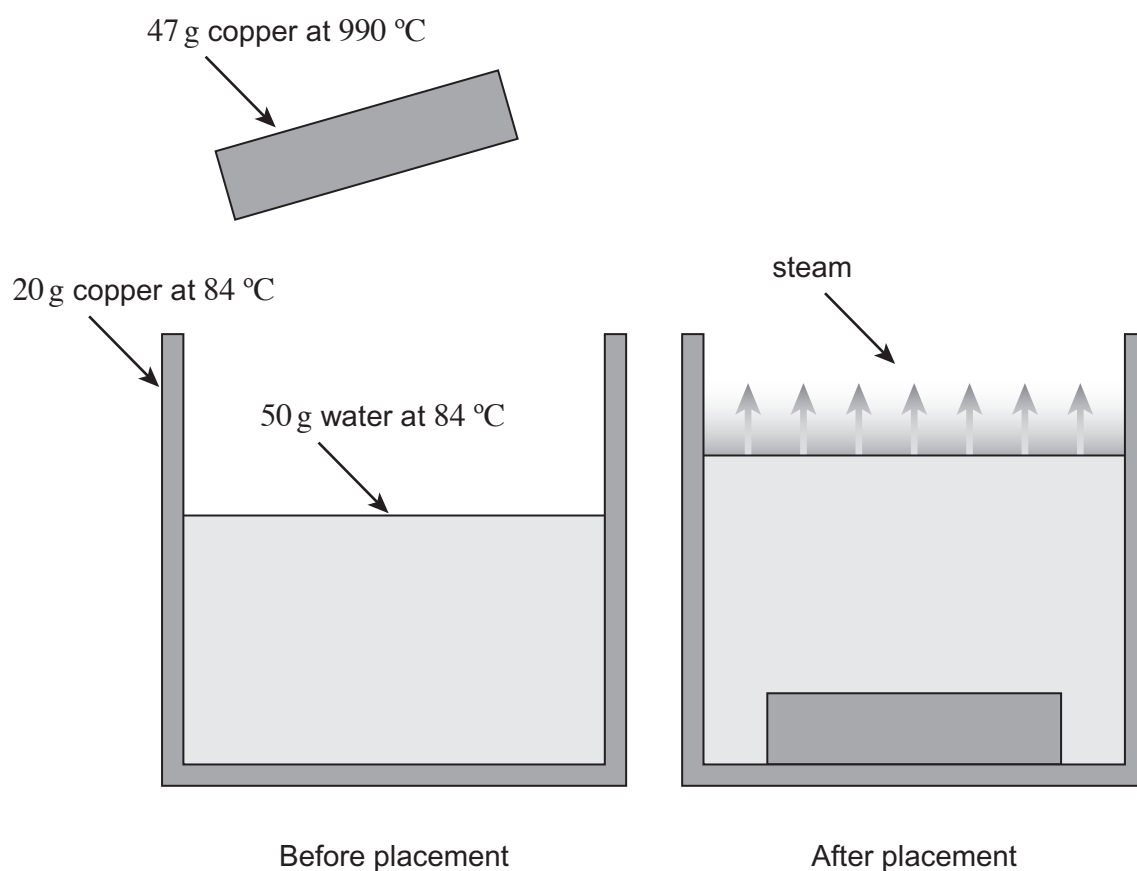
- 4 (b) An insulated copper can of mass 20 g contains 50 g of water both at a temperature of 84 °C. A block of copper of mass 47 g at a temperature of 990 °C is lowered into the water as shown in **Figure 2**. As a result, the temperature of the can and its contents reaches 100 °C and some of the water turns to steam.

specific heat capacity of copper = $390 \text{ J kg}^{-1} \text{ K}^{-1}$

specific heat capacity of water = $4200 \text{ J kg}^{-1} \text{ K}^{-1}$

specific latent heat of vaporisation of water = $2.3 \times 10^6 \text{ J kg}^{-1}$

Figure 2



- 4 (b) (i)** Calculate how much thermal energy is transferred from the copper block as it cools to 100 °C.

Give your answer to an appropriate number of significant figures.

[2 marks]

thermal energy transferred J

- 4 (b) (ii)** Calculate how much of this thermal energy is available to make steam.
Assume no heat is lost to the surroundings.

[2 marks]

available thermal energy J

- 4 (b) (iii)** Calculate the maximum mass of steam that may be produced.

[1 mark]

mass kg

7

Turn over ►



- 5 (a)** A nuclear reactor core is contained in a steel vessel surrounded by concrete. State and explain the purpose of the concrete other than its structural function.

[2 marks]

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- 5 (b)** A quantity of highly active waste removed from a nuclear reactor consists of similar amounts of two radioisotopes, X and Y. X has a half-life of about 20 days and emits γ rays and β^- particles. Y has a half-life of about 20 years and emits α particles. Assume that both X and Y become relatively stable after their initial decays.

Discuss the problems of storing the waste until it is safe and describe and explain the way in which the waste would normally be treated.

Your account should include details of:

- a comparison of the storage problems associated with X and Y in both the short term and the long term
- how the waste is treated initially at the reactor site and how it could be stored safely for a long time.

The quality of your written communication will be assessed in your answer.

[6 marks]

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8

END OF SECTION A



There are no questions printed on this page

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



A-LEVEL PHYSICS A

PHYA5 - 1 – Nuclear and Thermal Physics
Mark scheme

2450
June 2014

Version: 1.0 Final

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

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Further copies of this Mark Scheme are available from aqa.org.uk

Question	Answers	Additional Comments/Guidance	Mark	ID details
1 (a)	the amount of energy required to separate a nucleus ✓ into its separate neutrons and protons/nucleons ✓ (or energy released on formation of a nucleus ✓ from its separate neutrons and protons/constituents ✓)	1 st mark is for correct energy flow direction 2 nd mark is for binding or separating nucleons (nucleus is in the question but a reference to an atom will lose the mark) ignore discussion of SNF etc both marks are independent	2	
1 (b)(i)	$2\text{}^1_0\text{n}$ or $\text{}^1_0\text{n} + \text{}^1_0\text{n}$ ✓	must see subscript and superscripts	1	
1 (b)(ii)	binding energy of U = 235×7.59 ✓ (= 1784 (MeV)) binding energy of Tc and In = $112 \times 8.36 + 122 \times 8.51$ ✓ (= 1975 (MeV)) energy released (=1975 – 1784) = 191 (MeV) ✓ (allow 190 MeV)	1 st mark is for 235×7.59 seen anywhere 2 nd mark for $112 \times 8.36 + 122 \times 8.51$ or 1975 is only given if there are no other terms or conversions added to the equation (ignore which way round the subtraction is positioned) Correct final answer can score 3 marks	3	
1(b)(iii)	energy released = $191 \times 1.60 \times 10^{-13}$ ✓ (= 3.06×10^{-11} J)	Allow CE from (b)(ii) working must be shown for a CE otherwise full marks can be given	2	

	loss of mass ($= E / c^2$) $= 2.91 \times 10^{-11} / (3.00 \times 10^8)^2$ $= 3.4 \times 10^{-28}$ (kg) ✓ or $= 191/931.5$ u ✓ ($= 0.205$ u) $= 0.205 \times 1.66 \times 10^{-27}$ (kg) $= 3.4 \times 10^{-28}$ (kg) ✓	for correct answer only note for CE answer = (b)(ii) $\times 1.78 \times 10^{-30}$ (2.01×10^{-27} is a common answer)		
1 (c)(i)	line or band from origin, starting at 45° up to Z approximately = 20 reading Z =80, N = 110→130 ✓	Initial gradient should be about 1 (ie Z=20 ; N = 15 → 25) and overall must show some concave curvature. (ignore slight waviness in the line) If band is shown take middle as the line If line stops at N>70 extrapolate line to N = 80 for marking	1	
1 (c)(ii)	Fission fragments are (likely) to be above/to the left of the line of stability ✓ fission fragments are (likely) to have a larger N/Z ratio than stable nuclei or fission fragments are neutron rich and become neutron or β^- emitters ✓	Ignore any reference to α emission. A candidate must make a choice for the first two marks. Stating that there are more neutrons than protons is not enough for a mark. 1st mark reference to graph 2nd mark – high N/Z ratio or neutron rich 3rd mark beta <u>minus</u> Note not just beta.	3	
Total			12	

Question	Answers	Additional Comments/Guidance	Mark	ID details
2 (a)(i)	$\lambda (= \ln 2 / T_{1/2} = 0.693 / 5740) = 1.2 \times 10^{-4} \text{ (yr}^{-1}\text{)} \checkmark$ $(1.21 \times 10^{-4} \text{ yr}^{-1})$	only allow $3.83 \times 10^{-12} \text{ s}^{-1}$ if the unit has been changed working is not necessary for mark	1	
2 (a)(ii)	(use of $N_t = N_0 e^{-\lambda t}$ and activity is proportional to N $A_t = A_0 e^{-\lambda t}$) $0.375 = \exp - (1.21 \times 10^{-4} \times t) \checkmark$ $t = \frac{\ln(\frac{1}{0.375})}{1.21 \times 10^{-4}} \checkmark$ $t = 8100 \text{ or } 8200 \text{ (yr)} \checkmark$	1 st mark substitution, allow EC from (a)(i) 2 nd mark rearranging, allow EC from (a)(i) Allow $t / T_{1/2} = 2^n$ approach 3 rd mark no EC (so it is not necessary to evaluate a CE) So max 2 for a CE Full marks can be given for final answer alone. A minus in the final answer will lose the last mark.	3	
2(b)(i) +2(b)(ii)	(it is difficult to measure accurately) the small drop/change in activity/count-rate the small change/drop in the ratio of C-14 to C-12 $\checkmark$ the activity would be very small/comparable to the background or the ratio of C-14 to C-12 is too small or there are too few <u>C-14</u> atoms or there is very little decay	1 st mark needs some reference to a change in count-rate or activity for the mark Be lenient in 2 nd mark In reading a script assume C-14 is the subject. Eg 'there is little activity to work with' scores mark. Also allow any reasonable suggestion. Eg carbon may have been removed by bonding to surrounding material. Don't allow, ' <u>All</u> the carbon has	2	

	or the level of C-14 (in the biosphere) is uncertain (this long ago)✓	decayed'.		
Total			6	

Question	Answers	Additional Comments/Guidance	Mark	ID details
3 (a)	the number of atoms in 12g of carbon-12 or the number of particles/atoms/molecules in one mole of substance ✓	Not – N_A quoted as a number	1	
3 (b)(i)	mean kinetic energy ($= \frac{3}{2} kT$) = $\frac{3}{2} \times 1.38 \times 10^{-23} \times (273 + 22)$ $= 6.1 \times 10^{-21}$ (J) ✓	6×10^{-21} J is not given mark	1	
3 (b)(ii)	mass of krypton atom $= 0.084 / 6.02 \times 10^{+23}$ ✓ $(= 1.4 \times 10^{-25} \text{ kg})$ $\overline{c^2} (= 2 \times \text{mean kinetic energy} / \text{mass})$ $= 2 \times 6.1 \times 10^{-21} / 1.4 \times 10^{-25})$ $= 8.7 - 8.8 \times 10^4$ ✓ $\text{m}^2 \text{ s}^{-2}$ or J kg^{-1} ✓	1 st mark is for the substitution which will normally be seen within a larger calculation. Allow CE from (b)(i) Working must be shown for a CE otherwise full marks can be given for correct answer only. No calculation marks if mass has a physics error i.e. no division by N_A note for CE answer = (b)(i) $\times 1.43 \times 10^{25}$	3	
3 (c)	(at the same temperature) the	1st mark requires the word	2	

	mean kinetic energy is the same Or Gases have equal $\frac{1}{2}mc_{rms}^2$ Or mass is inversely proportional to mean square speed / $m \propto 1/\overline{c^2}$ ✓ $\overline{c^2}$ or mean square speed of krypton is less ✓	<u>mean/average</u> or equivalent in an algebraic term 2nd mark 'It' will be taken to mean krypton. So, 'It is less' can gain a mark Allow 'heavier' to mean more massive' Allow vague statements like speed is less for 2nd mark but not in the first mark		
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Total			7	
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Question	Answers	Additional Comments/Guidance	Mark	ID details
4 (a)	the energy required to change the state of a unit mass of water to steam/gas ✓ when at its boiling point temperature /100°C / without a change in temperature) ✓	Allow 1 kg in place of unit. Allow liquid to vapour/gas without reference to water. Don't allow 'evaporation' in first mark.	2	
4 (b)(i)	thermal energy given by copper block (= $mc\Delta T$) = $0.047 \times 390 \times (990 - 100)$ = 1.6×10^4 (J) ✓ 2 sig figs ✓	Can gain full marks without showing working A negative answer is not given credit. sig fig mark stands alone	2	
4(b)(ii)	thermal energy gained by water		2	

	and copper container $(=mc\Delta T_{\text{water}} + mc\Delta T_{\text{copper}})$ $= 0.050 \times 4200 \times (100 - 84) +$ $0.020 \times 390 \times (100 - 84)$ or $= 3500 \text{ (J)} \checkmark (3485 \text{ J})$ available heat energy $(=1.6 \times 10^4$ $- 3500) = 1.3 \times 10^4 \text{ (J)} \checkmark$ allow both 12000J and 13000 J	Allow CE from (b)(i) working must be shown for a CE Take care in awarding full marks for the final answer – missing out the copper container may result in the correct answer but not be worth any marks because of a physics error. (3485 is a mark in itself) ignore sign of final answer in CE (many CE's should result in a negative answer)		
4(b)(iii)	(using $Q = ml$) $m = 1.3 \times 10^4 / 2.3 \times 10^6$ $= 0.0057 \text{ (kg)} \checkmark$ Allow 0.006 but not 0.0060 (kg)	Allow CE from (b)(ii) answers between 0.0052 $\rightarrow$ 0.0057 kg resulting from use of 12000 and 13000 J	1	
Total			7	

Question	Answers	Additional Comments/Guidance	Mark	ID details
5 (a)	It forms a (biological) shield to reduce the (intensity of) radiation from/ for protection from $\checkmark$ <u>neutron</u> (and gamma) radiation $\checkmark$	Be lenient in 1st mark. 'Absorbs radiation' is enough to score.	2	
5(b)	See below - QWC		6	
Total			8	

QWC Mark Scheme

question	answers	extra information	mark
5 (b)			6
Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should also refer to the information on page 4 and apply a 'best-fit' approach to the marking.			
0 marks	Level 1 (1–2 marks)	Level 2 (3–4 marks)	Level 3 (5–6 marks)
	Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. There will be a few of the guidance points mentioned, but there will be little cohesion in the writing. Before taking the above into consideration a candidate making two or less relevant	Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. Before taking the above into consideration a candidate making three or four relevant statements from any	High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. Before taking the above into consideration a candidate making five or more relevant statements from two or three groups of marking points listed below will be placed

	statements from any of the three groups of marking points listed below is placed in this level. One point for one mark and two points for two marks	of the three groups of marking points listed below will be placed in this level. If all the statements come from only one group a score of 3 marks will be given. Four points from at least two groups will score 4 marks.	in this level. Six statements covering all three groups scores 6 marks but if five or more only come from two groups a maximum score of 5 may be awarded. Significant errors in the physics or order of events will exclude a candidate from this top level.
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examples of the points made in the response	extra information
Statements expected in a competent answer should include some of the following marking points. X group X ($\beta^- \gamma$) needs significant screening(allow lead here) is highly active therefore produces heat as activity $\propto 1/\text{half-life}$ (only counted once regardless of which group it is in) so lasts for a short time quoted as 80 days or more Y group Y (α) is easy to screen with metal container (if metal is quoted it must be realistic ie not lead) as activity $\propto 1/\text{half-life}$ (only counted once) is active for a very long time quoted as 80 years or more problems over container fatigue Treatment group By remote control remove waste <u>initially</u> place in a cooling pond/water tank the water acts as a shield water dissipates heat/lowers temperature <u>cooling pond</u> is on site/close to source as activity $\propto 1/\text{half-life}$(only counted once)	Marking strategy add up points made by candidates from the list to give an initial score. Low band If 2 points or less are given the number will be the lower band score. Middle Band If 3 points or 4 are given this is the score provided some points are given in two of the groups. Otherwise a score of 3 is given. Top band If 5 or 6 points are given this is the score but some must be made in each of the 3 groups. If from 2 groups score 5 if from 1 group score 3. If the script gives points but they are out of order, eg. put in steel barrels and then place in cooling ponds, Or if some true facts are mixed with some erroneous ones the candidate cannot be in the top band. Once the script has been read through the mark may be adjusted as a consequence of the organisation and style of the writing. facts must be related to the situation to be of value. So 'Alpha radiation is highly ionising and

keep for 1 – 3 years – it will then be cooler highly active waste will be greatly reduced make suggestions for longer term storage – vitrify the active material (to prevent leaking) store underground storage/salt mines in barrels / steel containers geological considerations etc	dangerous to the body' is not a main fact as it is assumed all radiations are harmful. Also facts must be realistic to be considered. 'It is best to store the radioactive waste in lead boxes to screen workers from the radiation' may have some merit but it would not count as a fact.
---	---

Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	



General Certificate of Education
Advanced Level Examination
June 2013

Physics A

PHYA5/1

Unit 5 Nuclear and Thermal Physics Section A

Thursday 20 June 2013 9.00 am to 10.45 am

For this paper you must have:

- a calculator
- a ruler
- a question paper/answer book for Section B (enclosed).

Time allowed

- The total time for both sections of this paper is 1 hour 45 minutes.
You are advised to spend approximately 55 minutes on this section.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this section is 40.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert in Section B.
- You will be marked on your ability to:
 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.



J U N 1 3 P H Y A 5 1 0 1

WMP/Jun13/PHYA5/1

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PHYA5/1

Section A

The maximum mark for this section is 40 marks.
You are advised to spend approximately 55 minutes on this section.

1 (a) (i) Define the atomic mass unit.

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(1 mark)

1 (a) (ii) State and explain how the mass of a ${}^4_2\text{He}$ nucleus is different from the total mass of its protons and neutrons when separated.

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(2 marks)

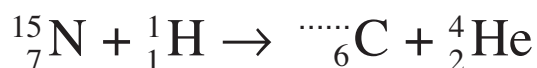
1 (b) Explain why nuclei in a star have to be at a high temperature for fusion to take place.

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(3 marks)



- 1 (c) (i)** In massive stars, nuclei of hydrogen ${}^1_1\text{H}$ are processed into nuclei of helium ${}^4_2\text{He}$ through a series of interactions involving carbon, nitrogen and oxygen called the CNO cycle.

Complete the nuclear equations below that represent the last two reactions in the series.



(3 marks)

- 1 (c) (ii)** The whole series of reactions is summarised by the following equation.



Calculate the energy, in MeV, that is released.

nuclear mass of ${}^4_2\text{He} = 4.00150 \text{ u}$

energy MeV
(3 marks)

12

Turn over ►



- 2 (a)** Describe the changes made inside a nuclear reactor to reduce its power output and explain the process involved.

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(2 marks)

- 2 (b)** State the main source of the highly radioactive waste from a nuclear reactor.

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(1 mark)

- 2 (c)** In a nuclear reactor, neutrons are released with high energies. The first few collisions of a neutron with the moderator transfer sufficient energy to excite nuclei of the moderator.

- 2 (c) (i)** Describe and explain the nature of the radiation that may be emitted from an excited nucleus of the moderator.

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(2 marks)

- 2 (c) (ii)** The subsequent collisions of a neutron with the moderator are elastic.

Describe what happens to the neutrons as a result of these subsequent collisions with the moderator.

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(2 marks)



- 3 A cola drink of mass 0.200 kg at a temperature of 3.0 °C is poured into a glass beaker. The beaker has a mass of 0.250 kg and is initially at a temperature of 30.0 °C.

specific heat capacity of glass = 840 J kg⁻¹ K⁻¹
specific heat capacity of cola = 4190 J kg⁻¹ K⁻¹

- 3 (i) Show that the final temperature, T_f , of the cola drink is about 8 °C when it reaches thermal equilibrium with the beaker.
Assume no heat is gained from or lost to the surroundings.

(2 marks)

- 3 (ii) The cola drink and beaker are cooled from T_f to a temperature of 3.0 °C by adding ice at a temperature of 0 °C.
Calculate the mass of ice added.
Assume no heat is gained from or lost to the surroundings.

specific heat capacity of water = 4190 J kg⁻¹ K⁻¹
specific latent heat of fusion of ice = 3.34×10^5 J kg⁻¹

mass kg
(3 marks)

5

Turn over ►



4 (a) Outline what is meant by an *ideal gas*.

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(2 marks)

4 (b) An ideal gas at a temperature of 22°C is trapped in a metal cylinder of volume 0.20 m^3 at a pressure of $1.6 \times 10^6\text{ Pa}$.

4 (b) (i) Calculate the number of moles of gas contained in the cylinder.

number of moles mol
(2 marks)

4 (b) (ii) The gas has a molar mass of $4.3 \times 10^{-2}\text{ kg mol}^{-1}$.

Calculate the density of the gas in the cylinder.

State an appropriate unit for your answer.

density unit
(3 marks)



- 4 (b) (iii)** The cylinder is taken to high altitude where the temperature is -50°C and the pressure is $3.6 \times 10^4 \text{ Pa}$. A valve on the cylinder is opened to allow gas to escape.

Calculate the mass of gas remaining in the cylinder when it reaches equilibrium with its surroundings.

Give your answer to an appropriate number of significant figures.

mass kg
(3 marks)

10

- 5** A radioactive source used in a school laboratory is thought to emit α particles and γ radiation. Describe an experiment that may be used to verify the types of radiation emitted by the source. The experiment described should allow you to determine how the intensity of radiation varies with distance in air or with the thickness of suitable absorbers.

Your answer should include:

- the apparatus you would use and any safety precautions you would take
- the measurements you would make
- how the measurements would be used to reach a final decision about the emitted radiation.

The quality of your written communication will be assessed in your answer.

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Turn over ►



[illegible]

(6 marks)

6





General Certificate of Education (A-level)
June 2013

Physics A

PHA5A

(Specification 2450)

Unit 5A: Nuclear and Thermal Physics

Astrophysics

Final

Mark Scheme

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Section A – Nuclear and Thermal Physics

Question	Part	Sub Part	Marking Guidance	Mark	Comments
1	(a)	(i)	1/12 the mass of an (atom) of $^{12}_6\text{C}$ / carbon-12 / C12✓	1	a reference to a nucleus loses the mark
1	(a)	(ii)	separated nucleons have a greater mass ✓ (than when inside a nucleus) because of the (binding) energy added to separate the nucleons or energy is released when a nucleus is formed (owtte) ✓	2	an answer starting with 'its' implies the nucleus marks are independent direction of energy flow or work done must be explicit
1	(b)		nuclei need to be close together (owtte) for the Strong Nuclear Force to be involved or for fusion to take place✓ but the electrostatic/electromagnetic force is repulsive (and tries to prevent this) ✓ (if the temperature is high then) the nuclei have (high) kinetic energy/speed (to overcome the repulsion) ✓	3	e.g. first mark – within the range of the SNF 3 rd mark is for a simple link between temperature and speed/KE
1	(c)	(i)	15 ✓ e^+ ✓ (or β^+ , $^0_1\beta$, ^0_1e) 12 ✓	3	give the middle mark easily for any e or β with a + in any position

1	(c)	(ii)	$\Delta\text{mass} = 4 \times 1.00728 - 4.00150 - (2 \times 9.11 \times 10^{-31} / 1.661 \times 10^{-27})$ or $\Delta\text{mass} = \{4 \times 1.00728 - 4.00150 - 2 \times 0.00055\}(\text{u}) \checkmark$ $\Delta\text{mass} = 0.02652(\text{u}) \checkmark$ $\Delta\text{binding energy} (= 0.02652 \times 931.5) \quad \{\text{allow } 931.3\}$ $\Delta\text{binding energy} = 24.7 \text{ MeV} \checkmark$	3	$(4 \times 1.00728 = 4.02912)$ 1 st mark – correct subtractions in any consistent unit. use of $m_p = 1.67 \times 10^{-27} \text{ kg}$ will gain this mark but will not gain the 2 nd as it will not produce an accurate enough result 2 nd mark – for calculated value 0.02652u $4.405 \times 10^{-29} \text{ kg}$ $3.364 \times 10^{-12} \text{ J}$ 3 rd mark – conversion to MeV conversion mark stands alone award 3 marks for answer provided some working shown – no working gets 2 marks (2sf expected)
2	(a)		insert control rods (further) into the nuclear core/reactor $\checkmark$ which will absorb (more) neutrons (reducing further fission reactions) $\checkmark$	2	a change must be implied for 2 marks marks by use of (further) or (more) allow answers that discuss shut down as well as power reduction If a statement is made that is wrong but not asked for limit the score to 1 mark (e.g. wrong reference to moderator)
2	(b)		fission fragments/daughter products or <u>spent/used</u> fuel/uranium rods (allow) plutonium (produced from U-238) $\checkmark$	1	not uranium on its own
2	(c)	(i)	γ (electromagnetic radiation is emitted) $\checkmark$ as the energy gaps are large (in a nucleus) as the nucleus de-excites down discrete energy levels to allow the nucleus to get to the ground level/state $\checkmark$ mark for reason	2	A reference to α or β loses this first mark 2 nd mark must imply energy levels or states

2	(c)	(ii)	momentum/<u>kinetic energy</u> is transferred (to the moderator atoms) or a neutron slows down/loses <u>kinetic energy</u> (with each collision) ✓ (eventually) reaching speeds associated with thermal random motion or reaches speeds which can cause fission (owtte)✓	2	
3		(i)	(heat supplied by glass = heat gained by cola) (use of $m_g c_g \Delta T_g = m_c c_c \Delta T_c$) $0.250 \times 840 \times (30.0 - T_f) = 0.200 \times 4190 \times (T_f - 3.0)$ ✓ $(210 \times 30 - 210 T_f = 838 T_f - 838 \times 3)$ $T_f = 8.4(1) (^{\circ}\text{C})$ ✓	2	1st mark for RHS or LHS of substituted equation 2nd mark for 8.4°C Alternatives: 8°C is substituted into equation (on either side shown will get mark)✓ resulting in 4620J~4190J ✓ or 8°C substituted into LHS ✓ (produces $\Delta T = 5.5^{\circ}\text{C}$ and hence) = 8.5°C ~ 8°C ✓ 8°C substituted into RHS✓ (produces $\Delta T = 20^{\circ}\text{C}$ and hence) = 10°C ~ 8°C ✓

3		(ii)	(heat gained by ice = heat lost by glass + heat lost by cola) (heat gained by ice = $mc\Delta T + ml$) heat gained by ice = $m \times 4190 \times 3.0 + m \times 3.34 \times 10^5$ ✓ (heat gained by ice = $m \times 346600$) heat lost by glass + heat lost by cola = $0.250 \times 840 \times (8.41 - 3.0) + 0.200 \times 4190 \times (8.41 - 3.0)$ ✓ (= 5670 J) $m (=5670/346600) = 0.016$ (kg) ✓ or (using cola returning to its original temperature) (heat supplied by glass = heat gained by ice) (heat gained by glass = $0.250 \times 840 \times (30.0 - 3.0)$) heat gained by glass = 5670 (J) ✓ (heat used by ice = $mc\Delta T + ml$) heat used by ice = $m(4190 \times 3.0 + 3.34 \times 10^5)$ ✓ (= $m(346600)$) $m (=5670/346600) = 0.016$ (kg) ✓	3	NB correct answer does not necessarily get full marks 3rd mark is only given if the previous 2 marks are awarded (especially look for $m \times 4190 \times 3.0$) the first two marks are given for the formation of the substituted equation not the calculated values if 8°C is used the final answer is 0.015 kg
4	(a)		molecules have negligible volume collisions are elastic the gas cannot be liquified there are no interactions between molecules (except during collisions) the gas obeys the (ideal) gas law / obeys Boyles law etc. at all temperatures/pressures any two lines ✓✓	2	a gas laws may be given as a formula
4	(b)	(i)	$n (= PV / RT) = 1.60 \times 10^6 \times 0.200 / (8.31 \times (273 + 22))$ ✓ = 130 or 131 mol ✓ (130.5 mol)	2	

4	(b)	(ii)	$\text{mass} = 130.5 \times 0.043 = 5.6 \text{ (kg)} \checkmark$ (5.61kg) $\text{density (= mass/volume)} = 5.61 / 0.200 = 28 \checkmark (28.1 \text{ kg m}^{-3})$ $\text{kg m}^{-3} \checkmark$	3	allow ecf from bi a numerical answer without working can gain the first two marks
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4	(b)	(iii)	$(V_2 = P_1 V_1 T_2 / P_2 T_1)$ $V_2 = 1.6 \times 10^6 \times .200 \times (273 - 50) / 3.6 \times 10^4 \times (273 + 22) \text{ or } 6.7(2)$ $(\text{m}^3) \checkmark$ $\text{mass remaining} = 5.61 \times 0.20 / 6.72 = 0.17 \text{ (kg)} \checkmark (0.167 \text{ kg})$ or $n = (PV / RT = 3.6 \times 10^4 \times 0.200 / (8.31 \times (273 - 50))) = 3.88(5) \text{ (mol)}$ $\checkmark$ $\text{mass remaining} = 3.885 \times 4.3 \times 10^{-2} = 0.17 \text{ (kg)} \checkmark$ 2 sig figs $\checkmark$	3	allow ecf from bii [reminder must see bii] look out for any 2 sf answer gets the mark
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5		The mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC).		
	QWC	Descriptor	Mark range	
	High Level (Good to excellent)	The candidate refers to all the necessary apparatus and records the count-rate at various distances (or thicknesses of absorber). The background is accounted for and a safety precaution is taken. The presence of an α source is deduced from the rapid fall in the count rate at 2 – 5 cm in air. The presence of a γ source is deduced from the existence of a count-rate above background beyond 30 -50 cm in air (or a range in any absorber greater than that of beta particles, e.g. 3 – 6 mm in Al) or from the intensity in air falling as an inverse square of distance or from an exponential fall with the thickness of a material e.g. lead. <i>The information should be well organised using appropriate specialist vocabulary. There should only be one or two spelling or grammatical errors for this mark.</i>	5-6	If more than one source is used or a different experiment than the question set is answered limit the mark to 4

	Intermediate Level (Modest to adequate)	The candidate refers to all the necessary apparatus and records the count-rate at different distances (or thicknesses of absorber). A safety precaution is stated. The presence of an α source is deduced from the rapid fall in the count rate at 2 – 5 cm in air and the γ source is deduced from the existence of a count-rate beyond 30 -50 cm in air (or appropriate range in any absorber, e.g. 3 -6 mm in Al). Some safety aspect is described. One other aspect of the experiment is given such as the background. <i>The grammar and spelling may have a few shortcomings but the ideas must be clear.</i>	3-4	To get an idea of where to place candidate look for 6 items: 1. Background which must be used in some way either for a comparison or subtracted appropriately 2. Recording some data with a named instrument
	Low Level (Poor to limited)	The candidate describes recording some results at different distances (or thicknesses of absorber) and gives some indication of how the presence of α or γ may be deduced from their range. Some attempt is made to cover another aspect of the experiment, which might be safety or background. <i>There may be many grammatical and spelling errors and the information may be poorly organised.</i>	1 - 2	3. Safety reference appropriate to a school setting – not lead lined gown for example 4. Record data with more than one absorber or distances 5. α source determined from results taken 6. γ source determined
		The description expected in a competent answer should include a coherent selection of the following points. apparatus: source, lead screen, ruler, γ ray and α particle detector such as a Geiger Muller tube, rate-meter or counter and stopwatch, named absorber of varying thicknesses may be used. safety: examples include, do not have source out of storage longer than necessary, use long tongs, use a lead screen between source and experimenter. measurements: with no source present switch on the counter for a fixed period measured by the stopwatch and record the number of counts or record the rate-meter reading with the source present measure and record the distance between the source and detector (or thickness of absorber) then switch on the counter for a fixed period measured by the stopwatch and record the number of counts or record the rate-meter reading repeat the readings for different distances (or thicknesses of absorber).		from results taken this is a harder mark to achieve it may involve establishing an inverse square fall in intensity in air or an exponential fall using thicknesses of lead if a continuous distribution is not used an absorber or distance in air that would just eliminate β (30-50cm air / 3-6mm Al) must be used with and without the source being present or compared to background

		use of measurements: for each count find the rate by dividing by the time if a rate-meter was not used subtract the background count-rate from each measured count-rate to obtain the corrected count-rate longer recording times may be used at longer distances (or thickness of absorber). plot a graph of (corrected) count-rate against distance (or thickness of absorber) or refer to tabulated values plot a graph of (corrected) count-rate against reciprocal of distance squared or equivalent linear graph to show inverse square relationship in air analysis: the presence of an α source is shown by a rapid fall in the (corrected) count-rate when the source detector distance is between 2 – 5 cm in air the presence of a γ source is shown if the <u>corrected</u> count-rate is still present when the source detector distance is greater than 30 cm in air (or at a range beyond that of beta particles in any other absorber, e.g. 3 mm in Al) the presence of a γ source is best shown by the graph of (corrected) count-rate against reciprocal of distance squared being a straight line through the origin		
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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	



General Certificate of Education
Advanced Level Examination
June 2012

Physics A

PHYA5/1

Unit 5 Nuclear and Thermal Physics Section A

Monday 18 June 2012 9.00 am to 10.45 am

For this paper you must have:

- a calculator
- a ruler
- a question paper/answer book for Section B (enclosed).

Time allowed

- The total time for both sections of this paper is 1 hour 45 minutes.
You are advised to spend approximately 55 minutes on this section.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this section is 40.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert in Section B.
- You will be marked on your ability to:
 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.



JUN12PHYA5101

WMP/Jun12/PHYA5/1

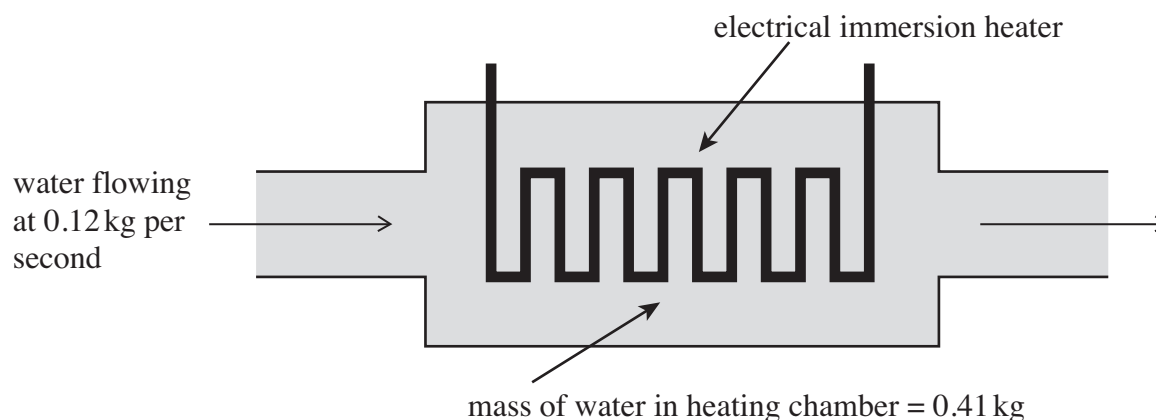
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PHYA5/1

Section A

The maximum mark for this section is 40 marks.
You are advised to spend approximately 55 minutes on this section.

- 1** An electrical immersion heater supplies 8.5 kJ of energy every second. Water flows through the heater at a rate of 0.12 kg s^{-1} as shown in **Figure 1**.

Figure 1

- 1 (a)** Assuming all the energy is transferred to the water, calculate the rise in temperature of the water as it flows through the heater.
specific heat capacity of water = $4200 \text{ J kg}^{-1} \text{ K}^{-1}$

answer = ... K
(2 marks)

- 1 (b)** The water suddenly stops flowing at the instant when its average temperature is 26°C . The mass of water trapped in the heater is 0.41 kg . Calculate the time taken for the water to reach 100°C if the immersion heater continues supplying energy at the same rate.

answer = ... s
(2 marks)



2 The isotope of uranium, $^{238}_{92}\text{U}$, decays into a stable isotope of lead, $^{206}_{82}\text{Pb}$, by means of a series of α and β^- decays.

2 (a) In this series of decays, α decay occurs 8 times and β^- decay occurs n times. Calculate n .

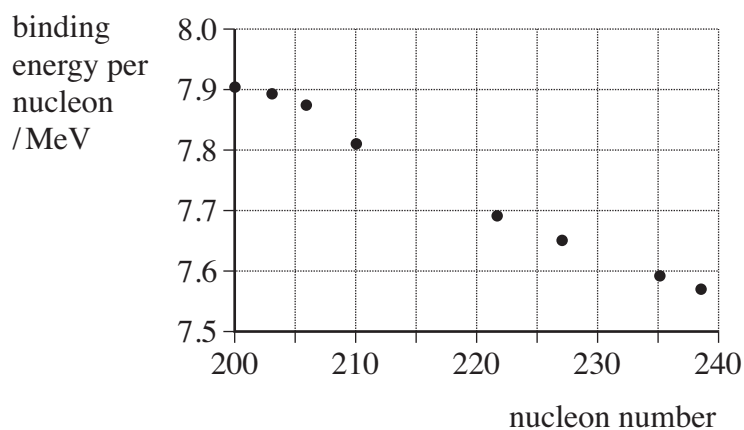
answer = ...
(1 mark)

2 (b) (i) Explain what is meant by the binding energy of a nucleus.

.....
.....
.....
(2 marks)

2 (b) (ii) **Figure 2** shows the binding energy per nucleon for some stable nuclides.

Figure 2



Use **Figure 2** to estimate the binding energy, in MeV, of the $^{206}_{82}\text{Pb}$ nucleus.

answer = ... MeV
(1 mark)

Turn over ►



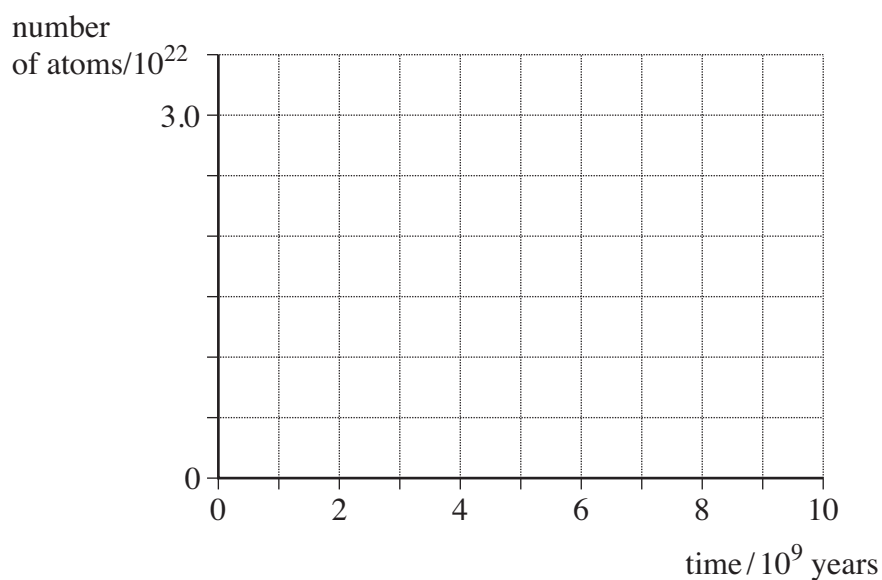
- 2 (c)** The half-life of $^{238}_{92}\text{U}$ is 4.5×10^9 years, which is much larger than all the other half-lives of the decays in the series.

A rock sample when formed originally contained 3.0×10^{22} atoms of $^{238}_{92}\text{U}$ and no $^{206}_{82}\text{Pb}$ atoms.

At any given time most of the atoms are either $^{238}_{92}\text{U}$ or $^{206}_{82}\text{Pb}$ with a negligible number of atoms in other forms in the decay series.

- 2 (c) (i)** Sketch on **Figure 3** graphs to show how the number of $^{238}_{92}\text{U}$ atoms and the number of $^{206}_{82}\text{Pb}$ atoms in the rock sample vary over a period of 1.0×10^{10} years from its formation.
Label your graphs U and Pb.

Figure 3



(2 marks)



- 2 (c) (ii)** A certain time, t , after its formation the sample contained twice as many ${}^{238}_{92}\text{U}$ atoms as ${}^{206}_{82}\text{Pb}$ atoms.
Show that the number of ${}^{238}_{92}\text{U}$ atoms in the rock sample at time t was 2.0×10^{22} .

(1 mark)

- 2 (c) (iii)** Calculate t in years.

answer = ... years
(3 marks)

10

Turn over ►



- 3 (a)** In a radioactivity experiment, background radiation is taken into account when taking corrected count rate readings in a laboratory. One source of background radiation is the rocks on which the laboratory is built. Give **two** other sources of background radiation.

source 1

source 2

(1 mark)

- 3 (b)** A γ ray detector with a cross-sectional area of $1.5 \times 10^{-3} \text{ m}^2$ when facing the source is placed 0.18 m from the source.
A corrected count rate of $0.62 \text{ counts s}^{-1}$ is recorded.

- 3 (b) (i)** Assume the source emits γ rays uniformly in all directions.
Show that the ratio

$$\frac{\text{number of } \gamma \text{ photons incident on detector}}{\text{number of } \gamma \text{ photons produced by source}}$$

is about 4×10^{-3} .

(2 marks)



- 3 (b) (ii)** The γ ray detector detects 1 in 400 of the γ photons incident on the facing surface of the detector.

Calculate the activity of the source. State an appropriate unit.

answer = ... unit
(3 marks)

- 3 (c)** Calculate the corrected count rate when the detector is moved 0.10 m further from the source.

answer = ... counts s⁻¹
(3 marks)



- 4 The pressure inside a bicycle tyre of volume $1.90 \times 10^{-3} \text{ m}^3$ is $3.20 \times 10^5 \text{ Pa}$ when the temperature is 285 K.

- 4 (a) (i) Calculate the number of moles of air in the tyre.

answer = ... mol
(1 mark)

- 4 (a) (ii) After the bicycle has been ridden the temperature of the air in the tyre is 295 K. Calculate the new pressure in the tyre assuming the volume is unchanged. Give your answer to an appropriate number of significant figures.

answer = ... Pa
(3 marks)

- 4 (b) Describe **one** way in which the motion of the molecules of air inside the bicycle tyre is similar and **one** way in which it is different at the two temperatures.

similar

.....

different

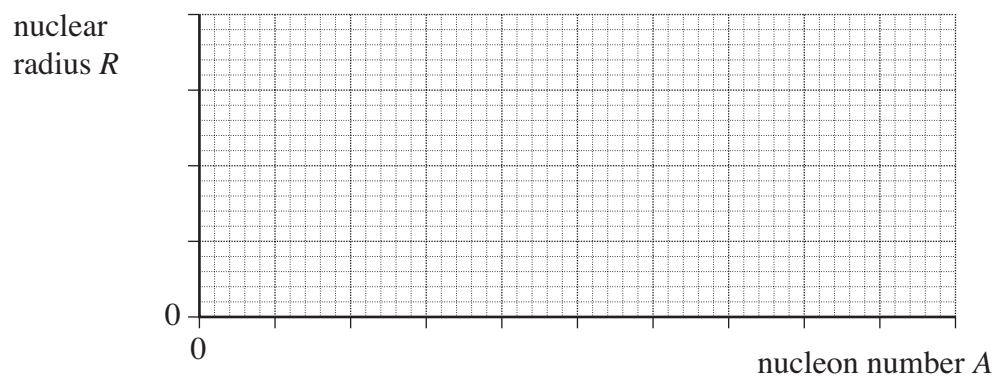
.....

(2 marks)



- 5 (a)** On **Figure 4** sketch a graph to show how the radius, R , of a nucleus varies with its nucleon number, A .

Figure 4



(1 mark)

- 5 (b) (i)** The radius of a gold-197 nucleus $^{197}_{79}\text{Au}$ is $6.87 \times 10^{-15} \text{ m}$.
Show that the density of this nucleus is about $2.4 \times 10^{17} \text{ kg m}^{-3}$.

(2 marks)

- 5 (b) (ii)** Using the data from part b(i) calculate the radius of an aluminium-27 nucleus, $^{27}_{13}\text{Al}$.

answer = ... m
(2 marks)

Turn over ►



- 5 (c)** Nuclear radii have been investigated using α particles in Rutherford scattering experiments and by using electrons in diffraction experiments. Make comparisons between these two methods of estimating the radius of a nucleus. Detail of any apparatus used is not required. For each method your answer should contain:

- the principles on which each experiment is based including a reference to an appropriate equation
- an explanation of what may limit the accuracy of each method
- a discussion of the advantages and disadvantages of each method

The quality of your written communication will be assessed in your answer.

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(6 marks)

END OF SECTION A

11



There are no questions printed on this page

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General Certificate of Education (A-level)
June 2012

Physics A

PHYA5/2A

(Specification 2450)

Unit 5/2A: Astrophysics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available from: aqa.org.uk

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Instructions to Examiners

- 1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.
- 2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	<i>see specific mark scheme</i>	5-6
Modest - Adequate	<i>see specific mark scheme</i>	3-4
Poor - Limited	<i>see specific mark scheme</i>	1-2
The description and/or explanation expected in a good answer should include a coherent account of the following points: <i>see specific mark scheme</i>		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

- 3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.
- 4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.
- 5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.
- 6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.
- 7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

GCE Physics, Specification A, PHYA5/1, Nuclear and Thermal Physics

1	a		$\Delta T = \left(\frac{\Delta Q}{mc}\right) = \frac{8.5 \times 10^3}{4200 \times 0.12} \checkmark$ 17 K $\checkmark$	2
1	b		$\left(\frac{\Delta T}{\Delta t} = \frac{\frac{\Delta Q}{\Delta t}}{mc}\right) = \frac{100 - 26}{\Delta t} = \frac{8.5 \times 10^3}{0.41 \times 4200} \checkmark$ $t = 15 \text{ s} \checkmark$	2
2	a		$({}^{206}_{76}\text{X} \rightarrow {}^{206}_{82}\text{Pb} + \beta + {}^0_{-1}\beta + \beta \times \bar{\nu}_e)$ $\beta = 6 \checkmark$	1
2	b	i	the energy required to split up the nucleus $\checkmark$ into its individual neutrons and protons/nucleons $\checkmark$ (or the energy released to form/hold the nucleus $\checkmark$ from its individual neutrons and protons/nucleons $\checkmark$)	2
2	b	ii	$7.88 \times 206 = 1620 \text{ MeV} \checkmark$ (allow 1600-1640 MeV)	1
2	c	i	U, a graph starting at 3×10^{22} showing exponential fall passing through 0.75×10^{22} near 9×10^9 years $\checkmark$ Pb, inverted graph of the above so that the graphs cross at 1.5×10^{22} near 4.5×10^9 years $\checkmark$	2
2	c	ii	(u represents the number of uranium atoms then) $\frac{u}{3 \times 10^{22} - u} = 2$ $u = 6 \times 10^{22} - 2u \checkmark$ $u = 2 \times 10^{22}$ atoms	1
2	c	iii	(use of $N = N_0 e^{-\lambda t}$) $2 \times 10^{22} = 3 \times 10^{22} \times e^{-\lambda t} \checkmark$ $t = \ln 1.5 / \lambda$ (use of $\lambda = \ln 2 / t_{1/2}$) $\lambda = \ln 2 / 4.5 \times 10^9 = 1.54 \times 10^{-10} \checkmark$ $t = 2.6 \times 10^9 \text{ years} \checkmark$ (or $2.7 \times 10^9 \text{ years}$)	3
3	a		any 2 from: the sun, cosmic rays, radon (in atmosphere), nuclear fallout (from previous weapon testing), any radioactive leak (may be given by name of incident) nuclear waste, carbon-14 $\checkmark$	1

3	b	i	(ratio of area of detector to surface area of sphere) ratio = $\frac{0.0015}{4\pi(0.18)^2}$ ✓ 0.0037 ✓ (0.00368)	2
3	b	ii	activity = $0.62/(0.00368 \times 1/400)$ give first mark if either factor is used. 67000 ✓ Bq accept s^{-1} or decay/photons/disintegrations s^{-1} but not counts s^{-1} ✓ (67400 Bq)	3
3	c		(use of the inverse square law) $\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2$ or calculating $k = 0.020$ from $I = k/x^2$ ✓ $I_2 = 0.62 \times \left(\frac{0.18}{0.28}\right)^2$ ✓ 0.26 counts s^{-1} ✓ (allow 0.24-0.26)	3
4	a	i	$n = PV/RT = 3.2 \times 10^5 \times 1.9 \times 10^{-3}/8.31 \times 285$ $n = 0.26$ mol ✓ (0.257 mol)	1
4	a	ii	$P_2 = \frac{T_2}{T_1} \times P_1 = \frac{295}{285} \times 3.20 \times 10^5$ ✓ 3.31×10^5 Pa ✓ (allow 3.30 - 3.35×10^5 Pa) 3 sig figs ✓ sig fig mark stands alone even with incorrect answer	3
4	b		similar - (rapid) random motion - range of speeds different - mean kinetic energy - root mean square speed - frequency of collisions	2
5	a		graph starting (steeply) near/at the origin and decreasing in gradient ✓	1
5	b	i	(use of density = mass/volume) $\frac{197 \times 1.67 \times 10^{-27}}{\frac{4}{3}\pi(6.87 \times 10^{-15})^3}$ ✓✓ mark for top line and mark for bottom line (allow use of 1.66×10^{-27}) Lose mass line mark if reference is made to mass of electrons $= 2.4(2) \times 10^{17}$ kg m^{-3}	2

5	b	ii	$R_{A1} = R_{Au} \left(\frac{A_{A1}}{A_{Au}} \right)^{\frac{1}{3}} = 6.87 \times 10^{-15} \left(\frac{27}{197} \right)^{\frac{1}{3}} \checkmark$ $= 3.54 \times 10^{-15} \text{ m } \checkmark$ or $r_0 = \frac{R}{A^{\frac{1}{3}}} = \frac{6.87 \times 10^{-15}}{197^{\frac{1}{3}}} = 1.18 \times 10^{-15} \text{ m } \checkmark$ $R = 1.18 \times 10^{-15} \times 27^{\frac{1}{3}} = 3.54 \times 10^{-15} \text{ m } \checkmark$ or $\text{volume} = \text{mass/density} = \frac{27 \times 1.67 \times 10^{-27}}{2.42 \times 10^{17}} = \frac{4}{3} \pi \times R^3 \checkmark$ $= 3.54 \times 10^{-15} \text{ m } \checkmark$	2
5	c		The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. <i>The candidate makes 5 to 6 points concerning the principles of the method, the limitations to the accuracy and the advantages and disadvantages of a particular method</i> Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. <i>The candidate makes 3 to 4 points concerning the principles of the method, the limitations to the accuracy and the advantages and disadvantages of a particular method</i> Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. <i>The candidate makes 1 to 2 points concerning the principles of the method, the limitations to the accuracy and the advantages and disadvantages of a particular method</i>	max 6

			The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences. principles • α scattering involves coulomb or electrostatic repulsion • electron diffraction treats the electron as a wave having a de Broglie wavelength • some reference to an equation, for example $\lambda = h/mv$; $eV = mv^2/2$; $Qq/4\pi\epsilon_0 r = E_\alpha$; $\sin\theta = 0.61\lambda/R$ • reference to first minimum for electron diffraction accuracy • α's only measure the least distance of approach, not the radius • α's have a finite size which must be taken into account • electrons need to have high speed/kinetic energy • to have a small wavelength or wavelength comparable to nuclear diameter, the wavelength determines the resolution • the wavelength needs to be of the same order as the nuclear diameter for significant diffraction • requirement to have a small collision region in order to measure the scattering angle accurately • importance in obtaining monoenergetic beams • cannot detect alpha particles with exactly 180° scattering • need for a thin sample to prevent multiple scattering advantages and disadvantages • α-particle measurements are disturbed by the nuclear recoil • Mark for α-particle measurements are disturbed by the SNF when coming close to the nucleus or electrons are not subject to the strong nuclear force. • A second mark can be given for reference to SNF if they add electrons are leptons or alpha particles are hadrons. • α's are scattered only by the protons and not all the nucleons that make up the nucleus • visibility – the first minimum of the electron diffraction is often difficult to determine as it superposes on other scattering events	
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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	



General Certificate of Education
Advanced Level Examination
June 2011

Physics A

PHYA5/1

Unit 5 Nuclear and Thermal Physics Section A

Monday 27 June 2011 9.00 am to 10.45 am

For this paper you must have:

- a calculator
- a ruler
- a question paper/answer book for Section B (enclosed).

Time allowed

- The total time for both sections of this paper is 1 hour 45 minutes.
You are advised to spend approximately 55 minutes on this section.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this section is 40.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert in Section B.
- You will be marked on your ability to:
 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.



J U N 1 1 P H Y A 5 1 0 1

WMP/Jun11/PHYA5/1

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PHYA5/1

Section A

The maximum mark for this section is 40 marks.
You are advised to spend approximately 55 minutes on this section.

- 1** The fissile isotope of uranium, ${}^{233}_{92}\text{U}$, has been used in some nuclear reactors. It is normally produced by neutron irradiation of thorium-232. An irradiated thorium nucleus emits a β^- particle to become an isotope of protactinium.

This isotope of protactinium may undergo β^- decay to become ${}^{233}_{92}\text{U}$.

- 1 (a)** Complete the following equation to show the β^- decay of protactinium.



(2 marks)

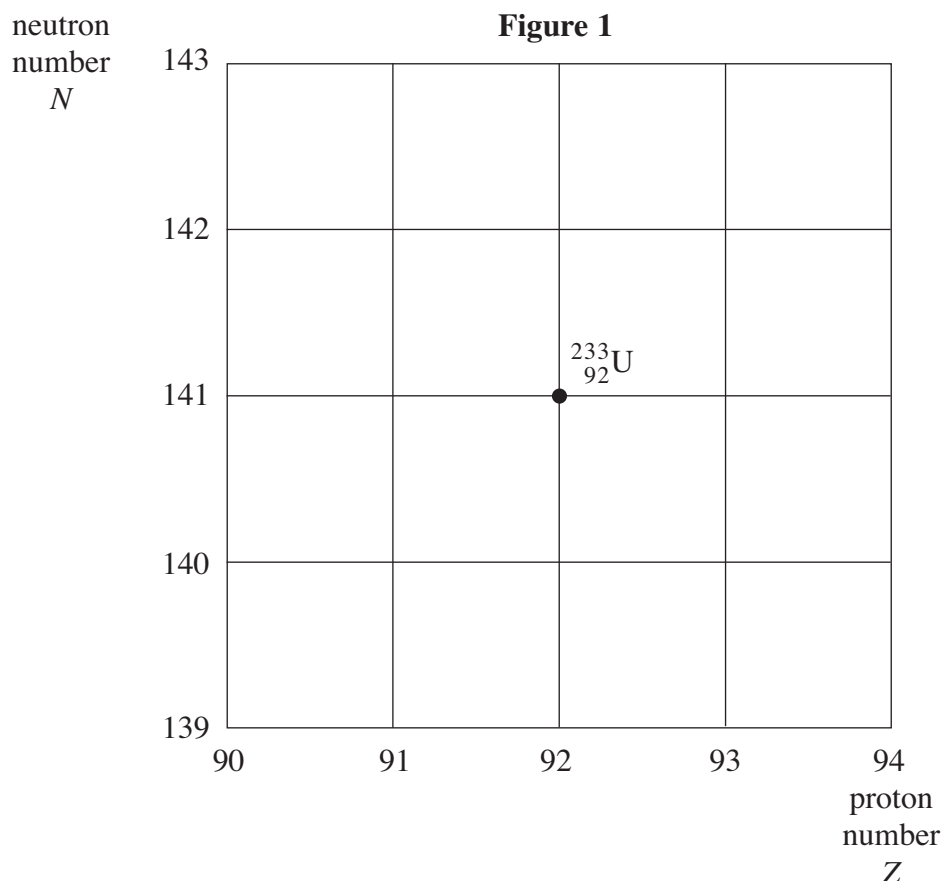
- 1 (b)** Two other nuclei, **P** and **Q**, can also decay into ${}^{233}_{92}\text{U}$.

P decays by β^+ decay to produce ${}^{233}_{92}\text{U}$.

Q decays by α emission to produce ${}^{233}_{92}\text{U}$.

Figure 1 shows a grid of neutron number against proton number with the position of the ${}^{233}_{92}\text{U}$ isotope shown.

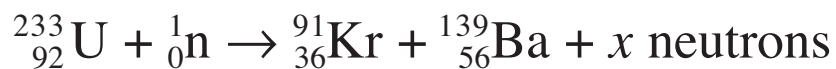
On the grid label the positions of the nuclei **P** and **Q**.



(2 marks)



- 1 (c) A typical fission reaction in the reactor is represented by



- 1 (c) (i) Calculate the number of neutrons, x .

answer = ...neutrons
(1 mark)

- 1 (c) (ii) Calculate the energy released, in MeV, in the fission reaction above.

mass of neutron = 1.00867 u

mass of ${}_{92}^{233}\text{U}$ nucleus = 232.98915 u

mass of ${}_{36}^{91}\text{Kr}$ nucleus = 90.90368 u

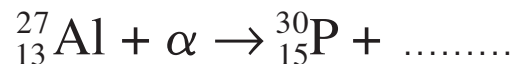
mass of ${}_{56}^{139}\text{Ba}$ nucleus = 138.87810 u

answer = ...MeV
(3 marks)



- 2** The first artificially produced isotope, phosphorus $^{30}_{15}\text{P}$, was formed by bombarding an aluminium isotope, $^{27}_{13}\text{Al}$, with an α particle.

- 2 (a)** Complete the following nuclear equation by identifying the missing particle.



(1 mark)

- 2 (b)** For the reaction to take place the α particle must come within a distance, d , from the centre of the aluminium nucleus.
Calculate d if the nuclear reaction occurs when the α particle is given an initial kinetic energy of at least $2.18 \times 10^{-12} \text{ J}$.

The electrostatic potential energy between two point charges Q_1 and Q_2 is equal to $\frac{Q_1 Q_2}{4\pi\epsilon_0 r}$ where r is the separation of the charges and ϵ_0 is the permittivity of free space.

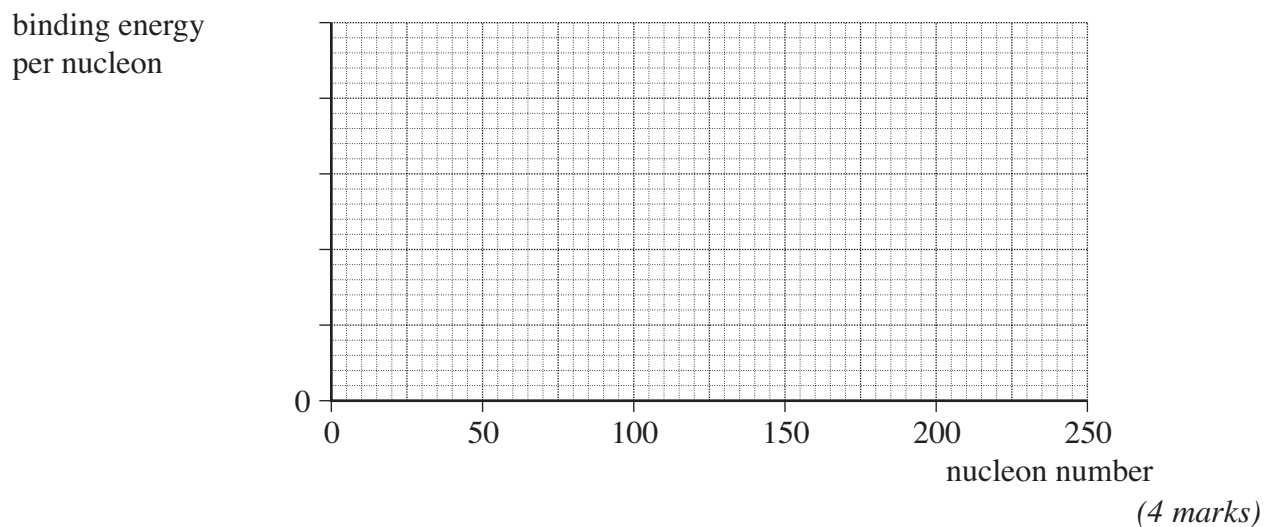
answer = ...m

(3 marks)



- 3 (a)** Sketch a graph of binding energy per nucleon against nucleon number for the naturally occurring nuclides on the axes given in **Figure 2**. Add values and a unit to the binding energy per nucleon axis.

Figure 2



- 3 (b)** Use the graph to explain how energy is released when some nuclides undergo fission and when other nuclides undergo fusion.

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(3 marks)

4 An electrical heater is placed in an insulated container holding 100 g of ice at a temperature of -14°C . The heater supplies energy at a rate of 98 joules per second.

4 (a) After an interval of 30 s, all the ice has reached a temperature of 0°C . Calculate the specific heat capacity of ice.

answer = ... $\text{J kg}^{-1} \text{K}^{-1}$
(2 marks)

4 (b) Show that the final temperature of the water formed when the heater is left on for a further 500 s is about 40°C .

specific heat capacity of water = $4200 \text{ J kg}^{-1} \text{K}^{-1}$

specific latent heat of fusion of water = $3.3 \times 10^5 \text{ J kg}^{-1}$

(3 marks)

4 (c) The whole procedure is repeated in an uninsulated container in a room at a temperature of 25°C . State and explain whether the final temperature of the water formed would be higher or lower than that calculated in part (b).

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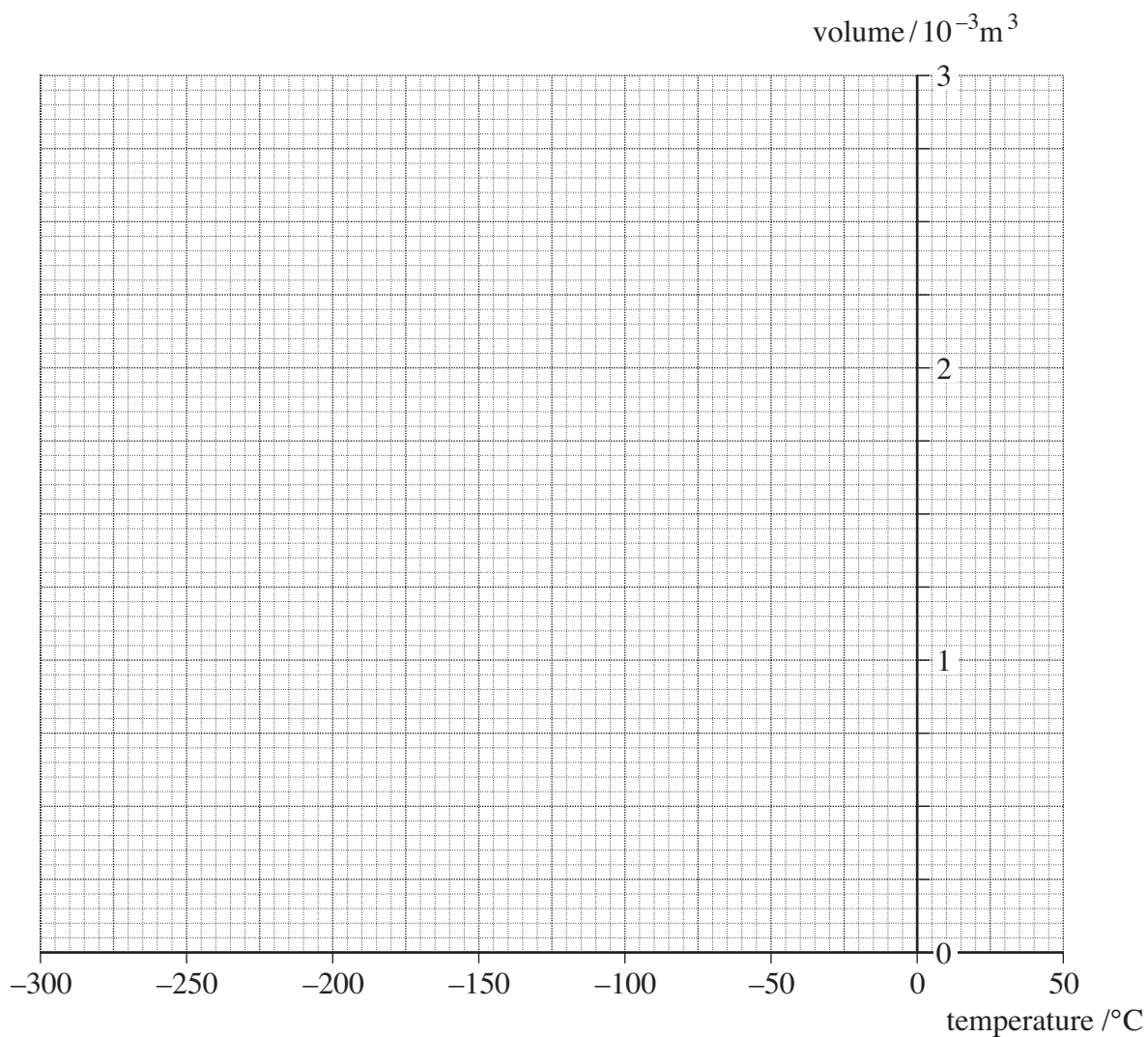
.....

(2 marks)



- 5** A fixed mass of ideal gas at a low temperature is trapped in a container at constant pressure. The gas is then heated and the volume of the container changes so that the pressure stays at $1.00 \times 10^5 \text{ Pa}$.
When the gas reaches a temperature of 0°C the volume is $2.20 \times 10^{-3} \text{ m}^3$.

- 5 (a)** Draw a graph on the axes below to show how the volume of the gas varies with temperature in $^\circ\text{C}$.



(2 marks)

- 5 (b)** Calculate the number of moles of gas present in the container.

answer = ...moles
(2 marks)

Turn over ►



- 5 (c) Calculate the average kinetic energy of a molecule when this gas is at a temperature of 50.0°C . Give your answer to an appropriate number of significant figures.

answer = ...J
(3 marks)

- 5 (d) Calculate the total internal energy of the gas at a temperature of 50.0°C .

answer = ...J
(1 mark)

- 5 (e) By considering the motion of the molecules explain how a gas exerts a pressure and why the volume of the container must change if the pressure is to remain constant as the temperature increases.

The quality of your written communication will be assessed in this question.

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General Certificate of Education (A-level)
June 2011

Physics A

PHYA5/2A

(Specification 2450)

Unit 5/2A: Astrophysics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available from: aqa.org.uk

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Instructions to Examiners

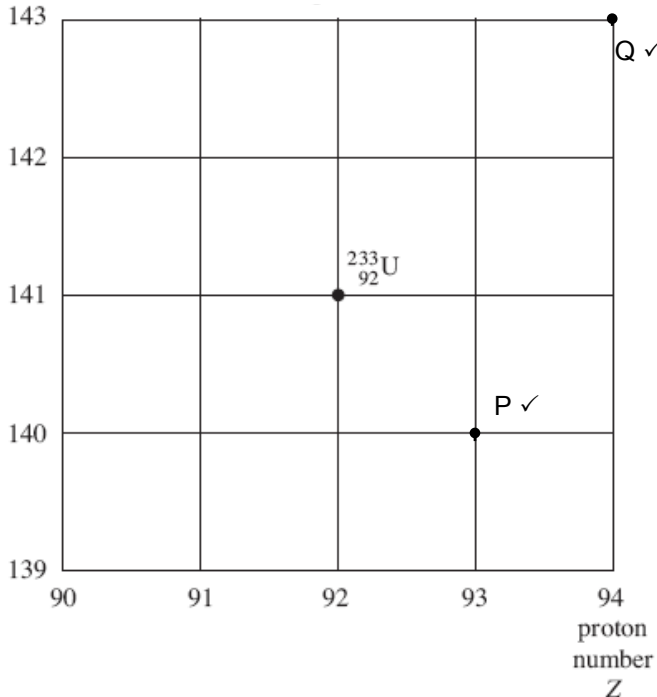
- 1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.
- 2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	<i>see specific mark scheme</i>	5-6
Modest - Adequate	<i>see specific mark scheme</i>	3-4
Poor - Limited	<i>see specific mark scheme</i>	1-2
The description and/or explanation expected in a good answer should include a coherent account of the following points: <i>see specific mark scheme</i>		

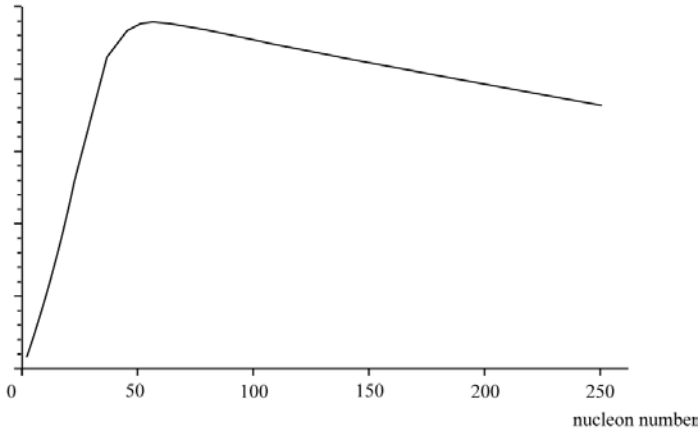
Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

- 3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.
- 4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.
- 5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.
- 6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.
- 7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

GCE Physics, Specification A, PHYA5/1, Nuclear and Thermal Physics

Question 1		
a	${}_{91}^{233}\text{Pa}$ ✓ anti (electron) neutrino ✓	2
b		2
c i	$x = 4$ ✓	1
c ii	mass defect = $[(232.98915 + 1.00867) - (90.90368 + 138.87810 + 4 \times 1.00867)] \text{ u}$ ✓ $= 0.18136 \text{ u}$ ✓ energy released $(= 0.18136 \times 931) = 169 \text{ (MeV)}$ ✓	3
Total		8

Question 2		
a	${}_{13}^{27}\text{Al} + \alpha \rightarrow {}_{15}^{30}\text{P} + {}_0^{(1)}\text{n}$ ✓	1
b	kinetic energy lost by the α particle approaching the nucleus is equal to the potential energy gain ✓ $2.18 \times 10^{-12} = \frac{1}{4\pi \times 8.85 \times 10^{-12}} \times \frac{13 \times 1.6 \times 10^{-19} \times 2 \times 1.6 \times 10^{-19}}{r}$ ✓ $r = 2.75 \times 10^{-15} \text{ (m)}$ ✓	3
Total		4

Question 3		
a	binding energy per nucleon  peak 8.7 (accept 8.0 – 9.2) ✓ in MeV ✓ (or peak 1.4×10^{-12} accept $1.3 - 1.5 \times 10^{-12}$ ✓ in J ✓) at nucleon number 50 – 60 ✓ accept 50 – 75 sharp rise from origin and moderate fall not below 2/3 of peak height ✓	4
b	energy is released/made available when binding energy per nucleon is increased ✓ in fission a (large) nucleus splits and in fusion (small) nuclei join ✓ the most stable nuclei are at a peak ✓ fusion occurs to the left of peak and fission to the right ✓	max 3
	Total	7

Question 4		
a	(use of $\Delta Q = mc\Delta T$) $30 \times 98 = 0.100 \times c \times 14$ ✓ $c = 2100 \text{ (J kg}^{-1} \text{ K}^{-1}\text{)}$ ✓	2
b	(use of $\Delta Q = ml + mc\Delta T$) $500 \times 98 = 0.100 \times 3.3 \times 10^5$ ✓ + $0.100 \times 4200 \times \Delta T$ ✓ $(\Delta T = 38^\circ\text{C})$ $T = 38^\circ\text{C}$ ✓	3
c	the temperature would be higher ✓ as the ice/water spends more time below 25°C or heat travels in the direction from hot to cold or ice/water first gains heat then loses heat any one line ✓	2
	Total	7

Question 5		
a	graph passes through given point $2.2 \times 10^{-3} \text{ m}^3$ at 0°C straight line with positive gradient ✓ (straight) line to aim or pass through -273°C at zero volume ✓	2
b	(use of $n = P V / R T$) $1.00 \times 10^5 \times 2.20 \times 10^{-3} / 8.31 \times 273$ ✓ $n = 0.0970$ (moles) ✓	2
c	(use of mean kinetic energy = $3/2 K T$) $= 3/2 \times 1.38 \times 10^{-23} \times 323$ ✓ 6.69×10^{-21} (J) ✓ 3 sfs ✓	3
d	total internal energy = $6.69 \times 10^{-21} \times 0.0970 \times 6.02 \times 10^{23} = 390$ (J) ✓	1
e	The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate provides a comprehensive and coherent sequence of ideas linking the motion of molecules to the pressure they exert on a container. At least three of the first four points listed below must be given in a logical order. The description should also show awareness of how a balance is maintained between the increase in speed and shortening of the time interval between collisions with the wall to maintain a constant pressure. To be in this band, reference must be made to force being the rate of change of momentum or how, in detail, the volume compensates for the increase in temperature. Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate provides a comprehensive list of ideas linking the motion of molecules to the pressure they exert on a container. At least three of the first four points listed below are given. The candidate also knows that the mean square speed of molecules is proportional to temperature. Using this knowledge, an attempt is made to explain how the pressure is constant.	max 6

	Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate attempts the question and refers to at least two of the points listed below. Incorrect, inappropriate or no response: 0 marks No answer or answer refers to unrelated, incorrect or inappropriate physics. Statements expected in a competent answer should include some of the following marking points. molecules are in rapid random motion/many molecules are involved molecules change their momentum or accelerate on collision with the walls reference to Newton's 2nd law either $F = ma$ or $F = \text{rate of change of momentum}$ reference to Newton's 3rd law between molecule and wall relate pressure to force $P = F/A$ mean square speed of molecules is proportional to temperature as temperature increases so does change of momentum or change in velocity compensated for by longer time between collisions as the temperature increases as the volume increases the surface area increases which reduces the pressure	
	Total	14

Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
TOTAL	



General Certificate of Education
Advanced Level Examination
June 2010

Physics A

PHYA5/1

Unit 5 Nuclear and Thermal Physics
Section A

Tuesday 29 June 2010 1.30 pm to 3.15 pm

For this paper you must have:

- a calculator
- a ruler
- a question paper/answer book for Section B (enclosed).

Time allowed

- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 55 minutes on this section.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this section is 40.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert in Section B.
- You will be marked on your ability to:
 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.



J U N 1 0 P H Y A 5 1 0 1

WMP/Jun10/PHYA5/1

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PHYA5/1

Section A

The maximum mark for this section is 40 marks. You are advised to spend approximately 55 minutes on this section.

- 1** Molten lead at its melting temperature of 327°C is poured into an iron mould where it solidifies. The temperature of the iron mould rises from 27°C to 84°C , at which the mould is in thermal equilibrium with the now solid lead.

mass of lead = 1.20 kg

specific latent heat of fusion of lead = $2.5 \times 10^4 \text{ J kg}^{-1}$

mass of iron mould = 3.00 kg

specific heat capacity of iron = $440 \text{ J kg}^{-1} \text{ K}^{-1}$

- 1 (a)** Calculate the heat energy absorbed by the iron mould.

answer = ... J
(2 marks)

- 1 (b)** Calculate the heat energy given out by the lead while it is changing state.

answer = ... J
(1 mark)



1 (c) Calculate the specific heat capacity of lead.

answer = ... $\text{J kg}^{-1} \text{K}^{-1}$
(3 marks)

1 (d) State **one** reason why the answer to part 1 (c) is only an approximation.

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(1 mark)

7

Turn over for the next question

Turn over ►



- 2 (a)** In a thermal nuclear reactor, one fission reaction typically releases 2 or 3 neutrons. Describe and explain how a constant rate of fission is maintained in a reactor by considering what events or sequence of events may happen to the released neutrons.

The quality of your written communication will be assessed in this question.

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(7 marks)



- 2 (b)** Uranium is an α emitter. Explain why spent fuel rods present a greater radiation hazard than unused uranium fuel rods.

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(3 marks)

10

Turn over for the next question

Turn over ►



- 3** The age of an ancient boat may be determined by comparing the radioactive decay of $^{14}_6\text{C}$ from living wood with that of wood taken from the ancient boat. A sample of 3.00×10^{23} atoms of carbon is removed for investigation from a block of living wood. In living wood one in 10^{12} of the carbon atoms is of the radioactive isotope $^{14}_6\text{C}$, which has a *decay constant* of $3.84 \times 10^{-12} \text{ s}^{-1}$.

- 3 (a)** What is meant by the decay constant?

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(1 mark)

- 3 (b)** Calculate the half-life of $^{14}_6\text{C}$ in years, giving your answer to an appropriate number of significant figures.

$$1 \text{ year} = 3.15 \times 10^7 \text{ s}$$

answer = ... years
(3 marks)

- 3 (c)** Show that the rate of decay of the $^{14}_6\text{C}$ atoms in the living wood sample is 1.15 Bq.

(2 marks)



- 3 (d)** A sample of 3.00×10^{23} atoms of carbon is removed from a piece of wood taken from the ancient boat. The rate of decay due to the $^{14}_6\text{C}$ atoms in this sample is 0.65 Bq. Calculate the age of the ancient boat in years.

answer = ... years
(3 marks)

- 3 (e)** Give **two** reasons why it is difficult to obtain a reliable age of the ancient boat from the carbon dating described.

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(2 marks)

11

Turn over for the next question

Turn over ►



4

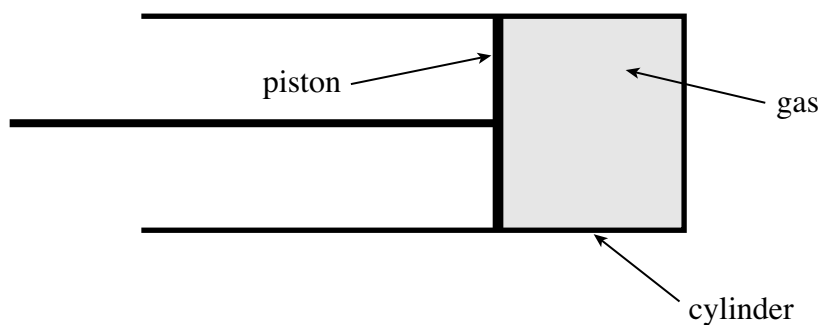
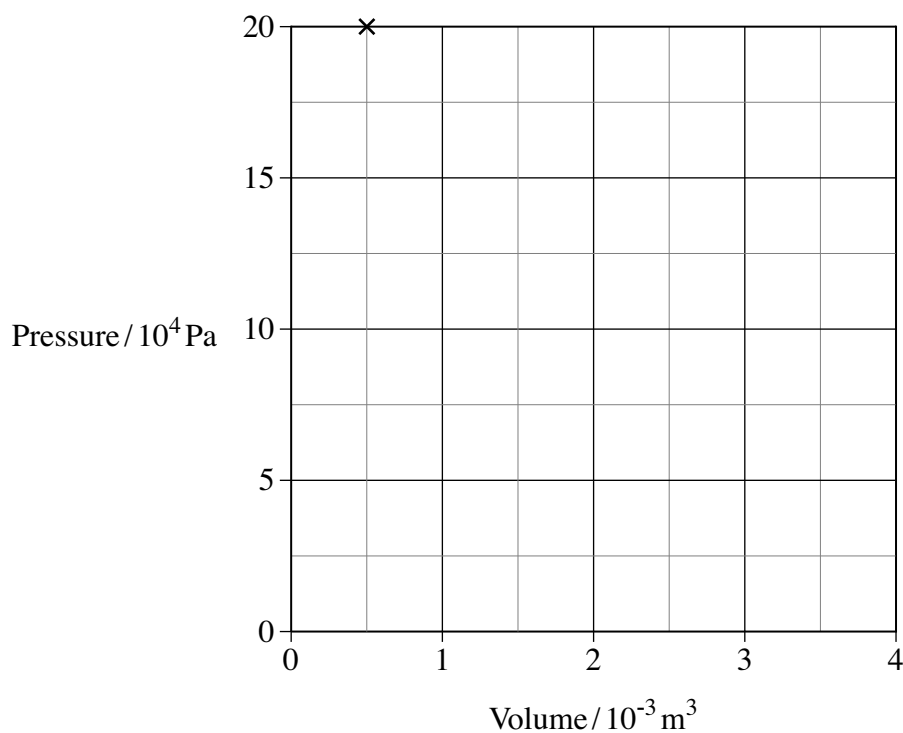
Figure 1

Figure 1 shows a cylinder, fitted with a gas-tight piston, containing an ideal gas at a constant temperature of 290 K. When the pressure, p , in the cylinder is $20 \times 10^4 \text{ Pa}$ the volume, V , is $0.5 \times 10^{-3} \text{ m}^3$.

Figure 2 shows this data plotted.

Figure 2

- 4 (a)** By plotting two or three additional points draw a graph, on the axes given in **Figure 2**, to show the relationship between pressure and volume as the piston is slowly pulled out. The temperature of the gas remains constant.

(3 marks)



4 (b) (i) Calculate the number of gas molecules in the cylinder.

answer = ... molecules
(2 marks)

4 (b) (ii) Calculate the total kinetic energy of the gas molecules.

answer = ... J
(3 marks)

4 (c) State **four** assumptions made in the molecular kinetic theory model of an ideal gas.

(i)

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(ii)

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(iii)

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(iv)

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(4 marks)

END OF SECTION A



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**General Certificate of Education
June 2010**

Physics A

PHYA5/2A

Astrophysics

Unit 5

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available to download from the AQA Website: www.aqa.org.uk

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Instructions to Examiners

- 1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.
- 2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	<i>see specific mark scheme</i>	5-6
Modest - Adequate	<i>see specific mark scheme</i>	3-4
Poor - Limited	<i>see specific mark scheme</i>	1-2
The description and/or explanation expected in a good answer should include a coherent account of the following points: <i>see specific mark scheme</i>		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

- 3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.
- 4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.
- 5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.
- 6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.
- 7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

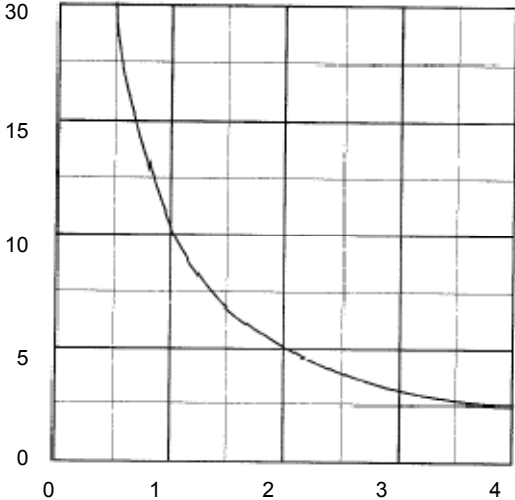
GCE Physics, Specification A, PHYA5/2A, Section A, Nuclear and Thermal Physics

Question 1		
(a)	using $Q = mc\Delta\theta$ $= 3.00 \times 440 \times (84-27) \checkmark$ $7.5 \times 10^4 \text{ (J)} \checkmark$	2
(b)	using $Q = ml$ $= 1.20 \times 2.5 \times 10^4$ $= 3.0 \times 10^4 \text{ (J)} \checkmark$	1
(c)	(heat supplied by lead changing state + heat supplied by cooling lead = heat gained by iron) $3.0 \times 10^4 + \text{heat supplied by cooling lead} = 7.5 \times 10^4 \checkmark$ heat supplied by cooling lead $= 4.5 \times 10^4 = mc\Delta\theta$ $c = 4.5 \times 10^4 / (1.2 \times (327 - 84)) \checkmark$ $c = 154 \text{ (J kg}^{-1} \text{ K}^{-1}) \checkmark$	3
(d)	any one idea $\checkmark$ no allowance has been made for heat loss to the surroundings or the specific heats may not be a constant over the range of temperatures calculated	1
	Total	7

Question 2		
(a)	The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate can explain the role of the moderator and control rods in maintaining a critical condition inside the reactor. The explanation is given in a clear sequence of events and the critical condition is defined in terms of neutrons. To obtain the top mark some other detail must be included. Such as, one of the alternative scattering or absorbing possibilities or appropriate reference to critical mass or detailed description of the feedback to adjust the position of the control rods etc. Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate has a clear idea of two of the following: the role of the moderator, the role of the control rods or can explain the critical condition. Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate explains that a released neutron is absorbed by uranium to cause a further fission. Alternatively the candidate may explain one of the following: the role of the moderator, the role of the control rods or can explain the critical condition. The explanation expected could include the following events that could happen to a released neutron. a neutron is slowed by the moderator taking about 50 collisions to reach thermal speeds then absorbed by uranium-235 to cause a fission event one neutron released goes on to cause a further fission is the critical condition a neutron may leave the reactor core without further interaction a neutron could be absorbed by uranium-238 a neutron could be absorbed by a control rod a neutron could be scattered by uranium-238 a neutron could be scattered by uranium-235	max 6

(b)	it is easy to stay out of range or easy to contain an α source or β/γ have greater range/are more difficult to screen ✓ most (fission fragments) are (more) radioactive/unstable ✓ and are initially most likely to be beta emitters/(which also) emit γ radiation/are neutron rich/heavy ✓ ionising radiation damages body tissue/is harmful ✓	max 3
	Total	9

Question 3		
(a)	probability of decay per unit time/given time period or fraction of atoms decaying per second or the rate of radioactive decay is proportional to the number of (unstable) nuclei and nuclear decay constant is the constant of proportionality ✓	1
(b)	use of $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ $T_{\frac{1}{2}} = \ln 2 / 3.84 \times 10^{-12} \text{ s} \checkmark (1.805 \times 10^{11} \text{ s})$ $= (1.805 \times 10^{11} / 3.15 \times 10^7) = 5730 \text{ y} \checkmark$ answer given to 3 sf ✓	3
(c)	number of nuclei = $N = 3.00 \times 10^{23} \times 1/10^{12} \checkmark$ $(= 3.00 \times 10^{11} \text{ nuclei})$ (using $\frac{\Delta N}{\Delta t} = -\lambda N$) rate of decay = $3.84 \times 10^{-12} \times 3.00 \times 10^{11} \checkmark$ $(= 1.15 \text{ Bq})$	2
(d)	$(N = N_0 e^{-\lambda t}$ and activity is proportional to the number of nuclei $A \propto N$ use of $A = A_0 e^{-\lambda t}$) $0.65 = 1.15 \times e^{-3.84 \times 10^{-12} t} \checkmark$ $t = \frac{\ln(\frac{1.15}{0.65})}{3.84 \times 10^{-12}}$ or $\frac{\ln(\frac{0.651}{1.15})}{-3.84 \times 10^{-12}} \checkmark$ $t = 4720 \text{ y} \checkmark$	3
(e)	the boat may have been made with the wood some time after the tree was cut down the background activity is high compared to the observed count rates the count rates are low or sample size/mass is small or there is statistical variation in the recorded results possible contamination uncertainty in the ratio of carbon-14 in carbon thousands of years ago any two ✓✓	2
	Total	11

Question 4														
(a)	pressure/10^4 Pa  curve with decreasing negative gradient that passes through the given point which does not touch the x axis ✓ <table border="1" data-bbox="410 952 873 1272"><thead><tr><th colspan="2">designated points</th></tr><tr><th>pressure/10^4 Pa</th><th>volume/10^{-3} m³</th></tr></thead><tbody><tr><td>10</td><td>1.0</td></tr><tr><td>5.0</td><td>2.0</td></tr><tr><td>4.0</td><td>2.5</td></tr><tr><td>2.5</td><td>4.0</td></tr></tbody></table> 2 of the designated points ✓✓ (one mark each)	designated points		pressure/ 10^4 Pa	volume/ 10^{-3} m ³	10	1.0	5.0	2.0	4.0	2.5	2.5	4.0	3
designated points														
pressure/ 10^4 Pa	volume/ 10^{-3} m ³													
10	1.0													
5.0	2.0													
4.0	2.5													
2.5	4.0													
(b) (i)	$N = PV/kT = 5 \times 10^4 \times 2 \times 10^{-3} / 1.38 \times 10^{-23} \times 290$ ✓ [or alternative use of $PV = nRT$ $5 \times 10^4 \times 2.0 \times 10^{-3} / 8.31 \times 290 = 0.0415$ moles] $= 2.50 \times 10^{22}$ molecules ✓	2												
(b) (ii)	(mean) kinetic energy of a molecule $= \frac{3}{2}kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 290$ ✓ ($= 6.00 \times 10^{-21}$ J) (total kinetic energy = mean kinetic energy $\times N$) $= 6.00 \times 10^{-21} \times 2.50 \times 10^{22}$ ✓ $= 150$ (J) ✓	3												

(c)	all molecules/atoms are identical molecules/atoms are in random motion Newtonian mechanics apply gas contains a large number of molecules the volume of gas molecules is negligible (compared to the volume occupied by the gas) or reference to point masses no force act between molecules except during collisions or the speed/velocity is constant between collisions or motion is in a straight line between collisions collisions are elastic or kinetic energy is conserved and of negligible duration any 4 ✓✓✓✓	max 4
	Total	12