Centre Number						Candidate Number				
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Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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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.

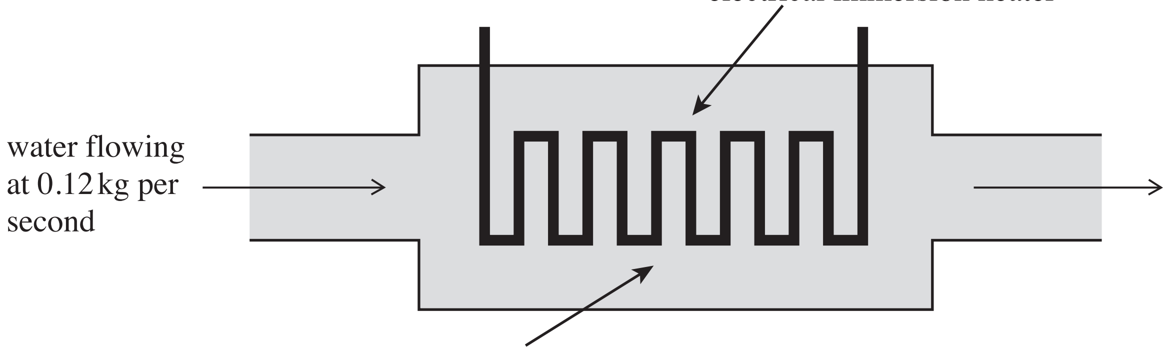
Do not write outside the box

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 $0.12\,\text{kg}\,\text{s}^{-1}$ 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 = $4200\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$

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)

4

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2 The isotope of uranium, ${}^{238}_{92}\mathrm{U}$, decays into a stable isotope of lead, ${}^{206}_{82}\mathrm{Pb}$, 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.

....

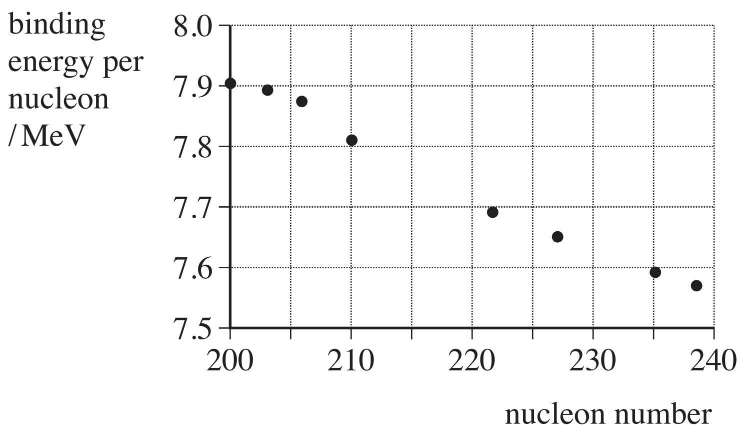
....

....

(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 ${}^{206}_{82}\mathrm{Pb}$ nucleus.

answer = ... MeV

(1 mark)

Turn over ▶

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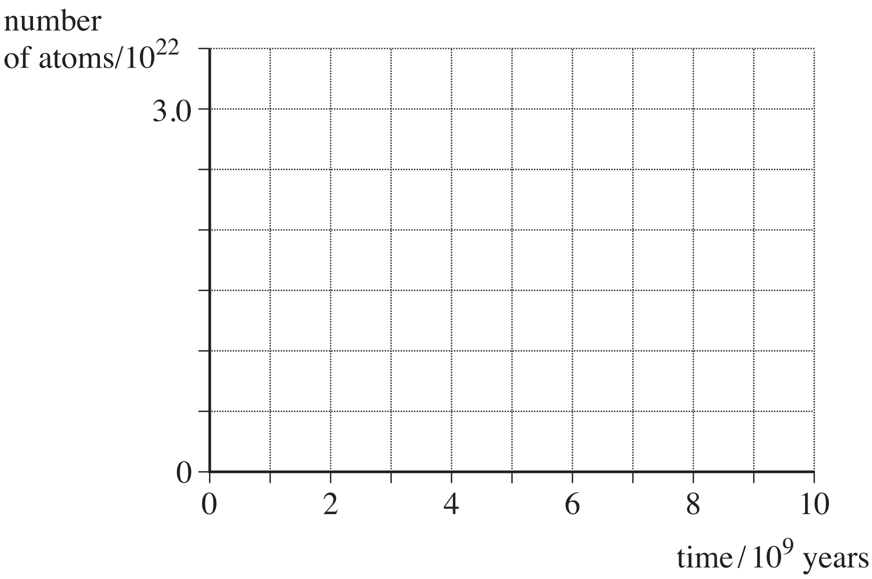
2 (c) The half-life of $^{238}_{92}U$ is 4.5×10^9 years, which is much larger than all the other half-lives of the decays in the series.

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

At any given time most of the atoms are either $^{238}_{92}U$ or $^{206}_{82}Pb$ 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 $^{238}_{92}U$ atoms and the number of $^{206}_{82}Pb$ 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)

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2 (c) (ii) A certain time, *t*, after its formation the sample contained twice as many $^{238}_{92}U$ atoms as $^{206}_{82}Pb$ atoms.
Show that the number of $^{238}_{92}U$ 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

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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 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)

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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)

9

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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)

6

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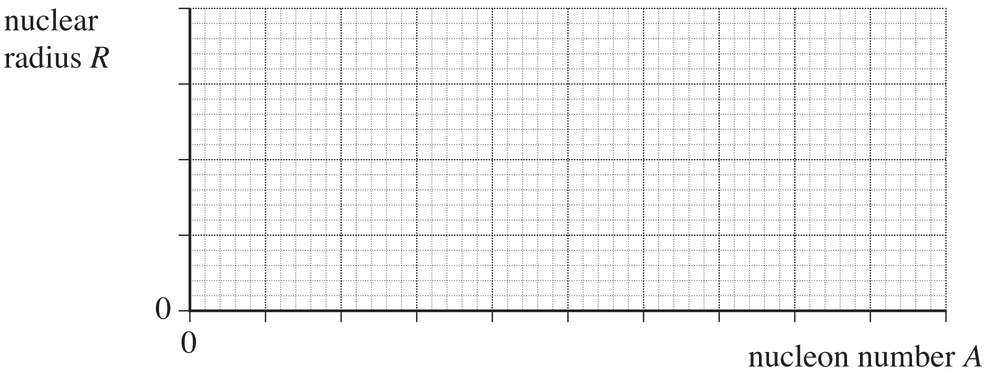
5 (a) On **Figure 4** sketch a graph to show how the radius, R, of a nucleus varies with its nucleon number, A.

Figure 4



(1 mark)

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

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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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