Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ______________________

Forename(s) ______________________

Candidate signature ______________________

A-level
PHYSICS A

Unit 5 Nuclear and Thermal Physics
Section A

Tuesday 28 June 2016 Morning

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.

Materials

For this paper you must have:
- a calculator
- a pencil and a ruler
- a question paper/answer book for Section B (enclosed).

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.

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Section A

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

1 (a) The radius of a nucleus may be determined by electron diffraction. In an electron diffraction experiment a beam of electrons is fired at oxygen-16 nuclei. Each electron has an energy of 5.94×10^{-11} J.

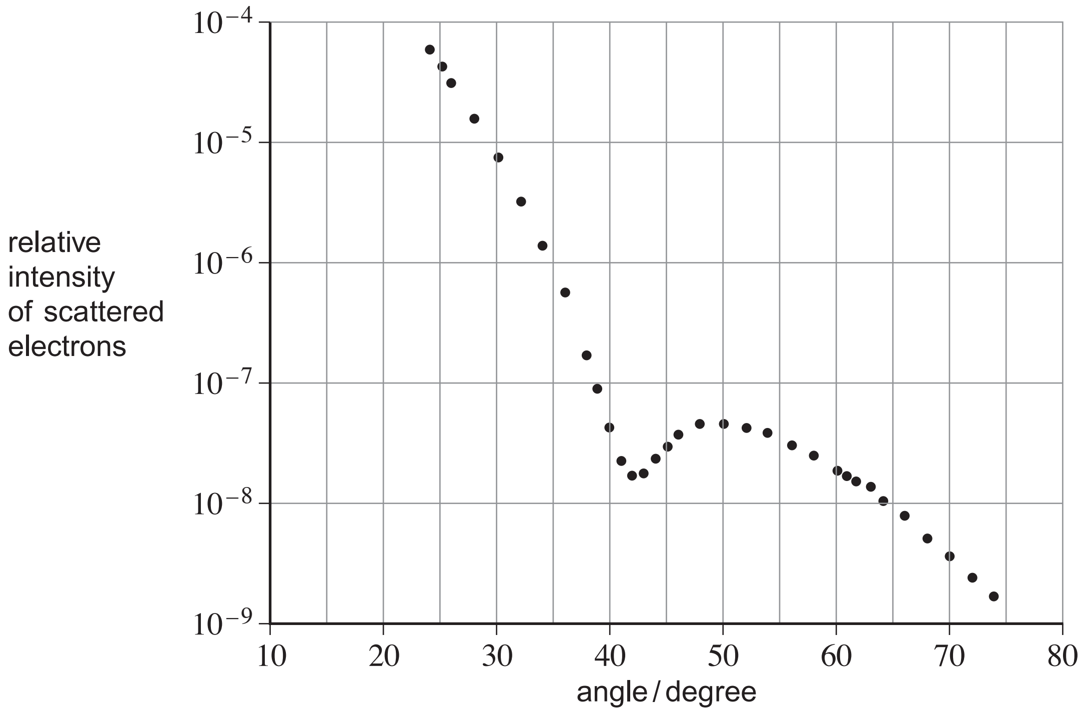
The approximation, $\text{momentum} = \dfrac{\text{energy}}{\text{speed of light}}$ can be used for electrons at this energy.

1 (a) (i) Show that the de Broglie wavelength λ of each electron in the beam is about 3.3×10^{-15} m.

[2 marks]

1 (a) (ii) **Figure 1** shows how the relative intensity of the scattered electrons varies with angle due to diffraction by the oxygen-16 nuclei. The angle is measured from the original direction of the beam.

Figure 1



The angle θ of the first minimum in the electron-diffraction pattern is given by

$$\sin\theta = \frac{0.61\lambda}{\text{nuclear radius}}$$

Calculate the radius of an oxygen-16 nucleus using information from **Figure 1**.

[1 mark]

radius = ______________________________ m

1 (b) Rutherford used the scattering of α particles to provide evidence for the structure of the atom.

1 (b) (i) Sketch a labelled diagram showing the experimental arrangement of the apparatus used by Rutherford.

[2 marks]

Question 1 continues on the next page

1 (b) (ii) State and explain the results of the scattering experiment.
Your answer should include the following:

- the main observations
- the significance of each observation
- how the observations placed an upper limit on the nuclear radius.

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

[6 marks]

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Turn over for the next question

11

2 (a) The exposure of the general public to background radiation has changed substantially over the past 100 years.
State **one** source of radiation that has contributed to this change.

[1 mark]

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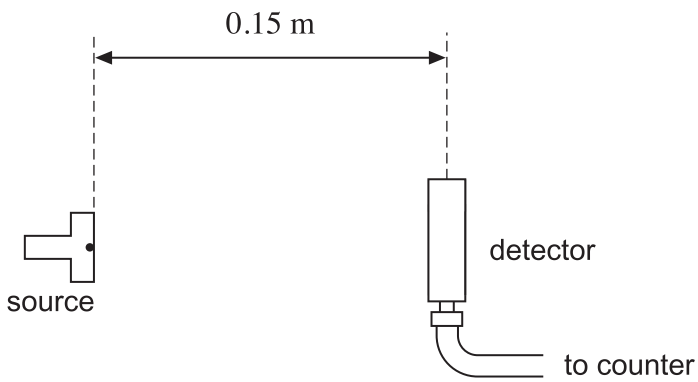
2 (b) A student measures background radiation using a detector and determines that background radiation has a mean count-rate of 40 counts per minute. She then places a γ ray source $0.15\ \mathrm{m}$ from the detector as shown in **Figure 2**.

Figure 2



With this separation the average count per minute was 2050.

The student then moves the detector further from the γ ray source and records the count-rate again.

2 (b) (i) Calculate the average count-rate she would expect to record when the source is placed $0.90\ \mathrm{m}$ from the detector.

[3 marks]

count-rate = ______________________ min^{-1}

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2 (b) (ii) The average count per minute of 2050 was determined from a measurement over a period of 5 minutes. Explain why the student might choose to record for longer than 5 minutes when the separation is 0.90 m.

[1 mark]

2 (b) (iii) When the detector was moved to 0.90 m the count-rate was lower than that calculated in part **(b)(i)**. It is suggested that the source may also emit β particles.
Explain how this can be checked.

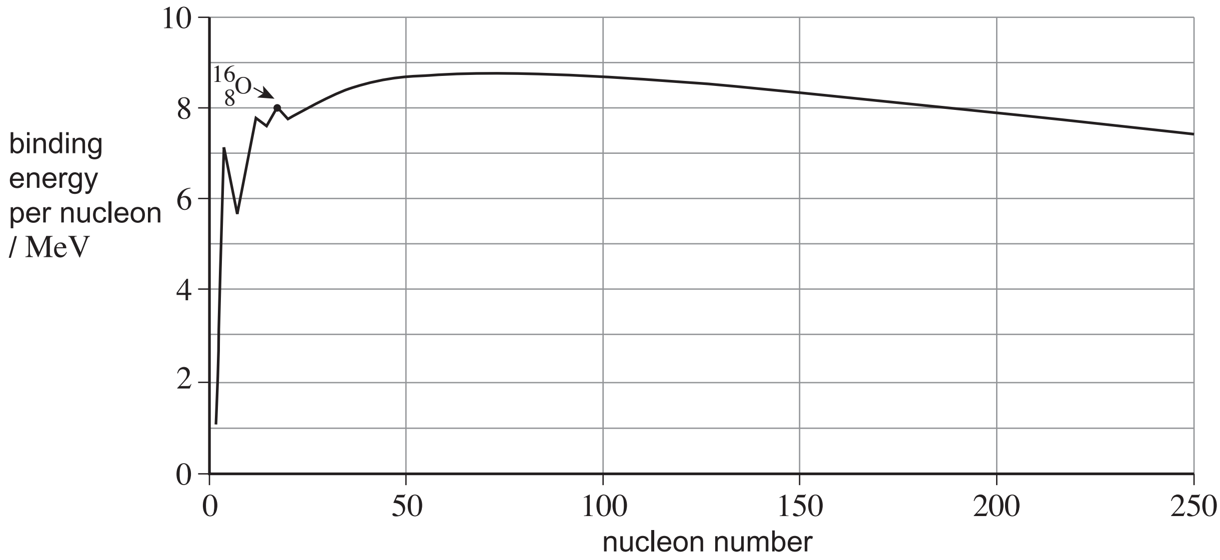
[2 marks]

7

Turn over for the next question

3 **Figure 3** shows how the binding energy per nucleon varies with nucleon number.

Figure 3



3 (a) (i) Fission and fusion are two nuclear processes in which energy can be released. Explain why nuclei that undergo fission are restricted to a different part of the graph than those that undergo fusion.

[2 marks]

3 (a) (ii) Explain, with reference to **Figure 3**, why the energy released per nucleon from fusion is greater than that from fission.

[2 marks]

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3 (b) (i) Calculate the mass difference, in kg, of the $^{16}_{8}O$ nucleus.

mass of $^{16}_{8}O$ nucleus = 15.991 u

[2 marks]

mass difference = ____________________ kg

3 (b) (ii) Using your answer to part **(b)(i)**, calculate the binding energy, in MeV, of an oxygen $^{16}_{8}O$ nucleus.

[1 mark]

binding energy = ____________________ MeV

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3 (b) (iii) Explain how the binding energy of an oxygen $^{16}_{8}O$ nucleus can be calculated with information obtained from **Figure 3**.

[1 mark]

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Turn to page 12 for the next question

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

4 (a) 'The pressure of an ideal gas is inversely proportional to its volume', is an incomplete statement of Boyle's law.

State **two** conditions necessary to complete the statement.

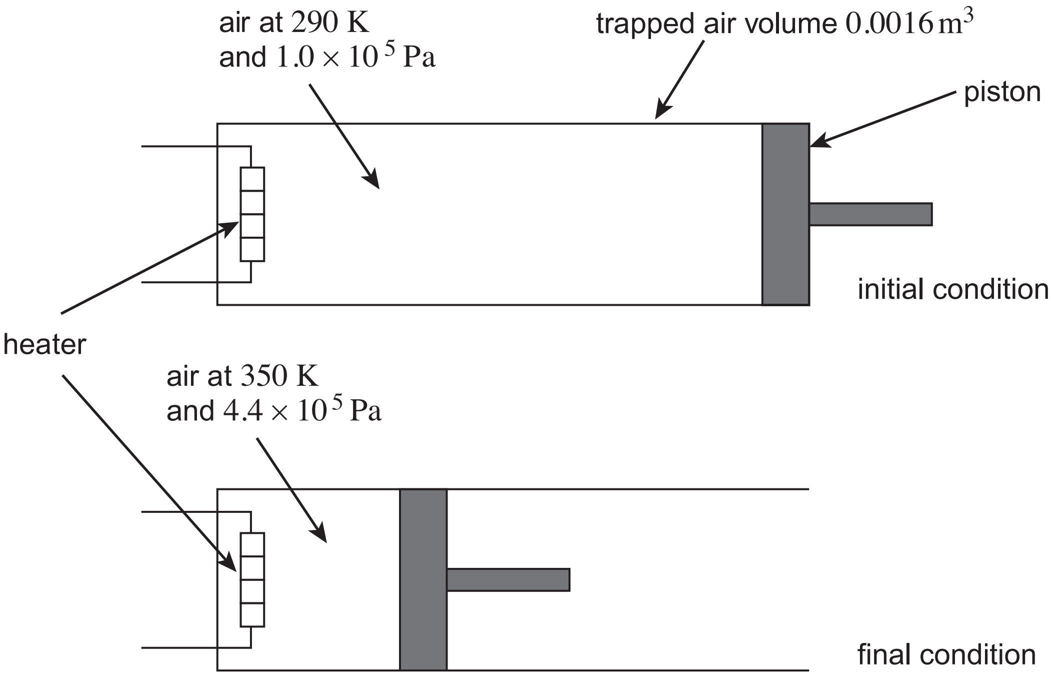
[2 marks]

1 ____

2 ____

4 (b) A volume of $0.0016\ \text{m}^3$ of air at a pressure of $1.0 \times 10^5\ \text{Pa}$ and a temperature of $290\ \text{K}$ is trapped in a cylinder. Under these conditions the volume of air occupied by $1.0\ \text{mol}$ is $0.024\ \text{m}^3$. The air in the cylinder is heated and at the same time compressed slowly by a piston. The initial condition and final condition of the trapped air are shown in **Figure 4**.

Figure 4



In the following calculations treat air as an ideal gas having a molar mass of $0.029\ \text{kg mol}^{-1}$.

4 (b) (i) Calculate the final volume of the air trapped in the cylinder.

[2 marks]

volume of air = ______________________ m^3

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4 (b) (ii) Calculate the number of moles of air in the cylinder.

[1 mark]

number of moles = ____________________________

4 (b) (iii) Calculate the initial density of air trapped in the cylinder.

[2 marks]

density = ______________________ $kg\ m^{-3}$

4 (c) State and explain what happens to the speed of molecules in a gas as the temperature increases.

[2 marks]

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9

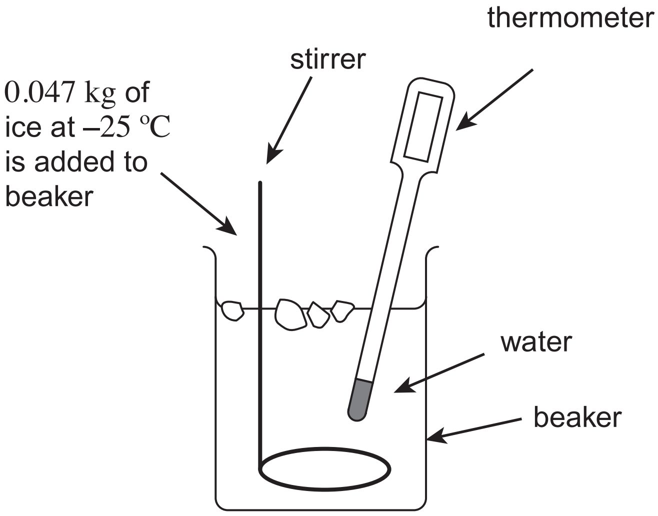
5 (a) Which statement explains why energy is needed to melt ice at 0 ºC to water at 0 ºC?
Place a tick (✓) in the right-hand column to show the correct answer.

[1 mark]

	✓ if correct
It provides the water with energy for its molecules to move faster.	
It breaks all the intermolecular bonds.	
It allows the molecules to vibrate with more kinetic energy.	
It breaks some intermolecular bonds.	

5 (b) **Figure 5** shows an experiment to measure the specific heat capacity of ice.

Figure 5



A student adds ice at a temperature of –25 ºC to water. The water is stirred continuously. Ice is added slowly until all the ice has melted and the temperature of the water decreases to 0 ºC. The mass of ice added during the experiment is 0.047 kg.

5 (b) (i) Calculate the energy required to melt the ice at a temperature of 0 ºC.
The specific latent heat of fusion of water is 3.3×10^5 J kg^{-1}.

[1 mark]

energy = ____________________________ J

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5 (b) (ii) The water loses 1.8×10^4 J of energy to the ice during the experiment.
Calculate the energy given to the ice to raise its temperature to $0\ ^{\circ}\mathrm{C}$. Assume that no energy is transferred to or from the surroundings and beaker.

[1 mark]

energy = ____________________________ J

5 (b) (iii) Calculate the specific heat capacity of the ice.
State an appropriate unit for your answer.

[2 marks]

specific heat capacity = ______________________ unit = __________

5

END OF QUESTIONS

There are no questions printed on this page

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