| Surname | | Other Names | |
|---|---|---|---|
| Centre Number | | Candidate Number | |
| Candidate Signature | | | |

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General Certificate of Education
January 2002
Advanced Level Examination

## PHYSICS (SPECIFICATION A) PHA7/W
## Unit 7 Nuclear Instability: Applied Physics Option

Monday 28 January 2002 Morning Session

**In addition to this paper you will require:**
- a calculator;
- a pencil and a ruler.

Time allowed: 1 hour 15 minutes

| For Examiner's Use | | | |
|---|---|---|---|
| Number | Mark | Number | Mark |
| 1 | | | |
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| Examiner's Initials | | | |

**Instructions**
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in the spaces provided. All working must be shown.
- Do all rough work in this book. Cross through any work you do not want marked.

**Information**
- The maximum mark for this paper is 40.
- Mark allocations are shown in brackets.
- The paper carries 10% of the total marks for Physics Advanced.
- A *Data Sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination.
- You are expected to use a calculator where appropriate.
- In questions requiring description and explanation you will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary where appropriate. The degree of legibility of your handwriting and the level of accuracy of your spelling, punctuation and grammar will also be taken into account.

**Data Sheet**

- A perforated *Data Sheet* is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- You may wish to detach this sheet before you begin work.

DATA SHEET

DATA SHEET

**TURN OVER FOR THE FIRST QUESTION**

LEAVE MARGIN BLANK

## SECTION A NUCLEAR INSTABILITY

Answer **all** parts of the question.

**1** (a) The nuclide $^{203}_{83}\text{Bi}$ can decay by *electron capture* to become an isotope of lead as shown in the following equation,

$$^{203}_{83}\text{Bi} + ^{0}_{-1}\text{e}^{-} \qquad ^{203}_{82}\text{Pb} + \nu_e + \text{Q}.$$

(i) Explain what is meant by electron capture.

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(ii) Give **one** reason why electromagnetic radiation is emitted following this process.

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(iii) Give the equation for another process in which $^{203}_{83}\text{Bi}$ is converted into an isotope of lead.

$$^{203}_{83}\text{Bi} \longrightarrow$$

*(5 marks)*

(b) The nuclide $^{203}_{83}Bi$ is also an α particle emitter. An initial measurement of the α particle activity of a sample of this isotope gives a corrected count rate of 1200 counts $s^{-1}$. After an interval of 24 hours the corrected rate falls to 290 counts $s^{-1}$.
Assume that corrections have been made for the radiation both from daughter products and background radiation.

(i) Show that the decay constant of $^{203}_{83}Bi$ is about $1.6 \times 10^{-5} s^{-1}$.

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(ii) Calculate the half-life of this sample.

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(iii) Calculate the number of $^{203}_{83}Bi$ nuclei in the sample when the corrected count rate was 1200 counts $s^{-1}$.

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*(5 marks)*

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**Turn over**

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## SECTION B APPLIED PHYSICS

Answer **all** questions.

**2** (a) The first law of thermodynamics can be written $\Delta Q = \Delta U + \Delta W$.

State the usual meaning of each term in the equation.

$\Delta Q$ ..........................................................................................................................

$\Delta U$ ..........................................................................................................................

$\Delta W$ ..........................................................................................................................

*(3 marks)*

(b) A fixed mass of gas in a cylinder is heated in two stages:

stage 1 at constant volume, when 10.0 kJ of heat is supplied,
stage 2 when it expands isothermally and does 6.0 kJ of work.

Apply the first law of thermodynamics to each of these processes and complete the table to show, for each process, the values of $\Delta Q$, $\Delta U$ and $\Delta W$.

| | $\Delta Q$ | $\Delta U$ | $\Delta W$ |
|---|---|---|---|
| stage 1 constant volume | +10 .0kJ | | |
| stage 2 isothermal | | | +6.0 kJ |

*(4 marks)*

7

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**3** A flywheel battery can be used in place of lead-acid batteries to provide a short-term electrical power supply when mains power fails. Energy is stored as rotational kinetic energy in a rapidly spinning rotor, which is driven up to speed by a mains-powered motor. To recover the energy, the motor is operated in reverse as a generator driven by the spinning rotor.

(a) The rotor of a flywheel battery is a thin-walled circular cylinder of mass 160 kg and mean radius 0.34 m, which can be rotated at a maximum safe angular speed of 44 000 rev min$^{-1}$.

Calculate

(i) the moment of inertia of the rotor about its own axis,

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(ii) the rotational kinetic energy stored in the rotating rotor when it spins at 44 000 rev min$^{-1}$.

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*(3 marks)*

(b) The manufacturer claims that the power loss due to friction when the rotor is running at its maximum safe angular speed is 2.0 W and that the mean power loss over the range of speeds from rest up to the maximum safe angular speed is 0.60 W.

Use the manufacturer's data to calculate

(i) the frictional torque acting on the rotor when spinning at its maximum safe angular speed,

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(ii) the time it takes to come to rest from this angular speed under the action of the frictional torque alone.

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*(2 marks)*

(c) When it is required to supply electrical power during a mains failure, the flywheel battery can supply a constant load of 2.5 kW for 17 hours. Calculate the rotor's angular speed at the end of this period if it starts at 44 000 rev min$^{-1}$.

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*(3 marks)*

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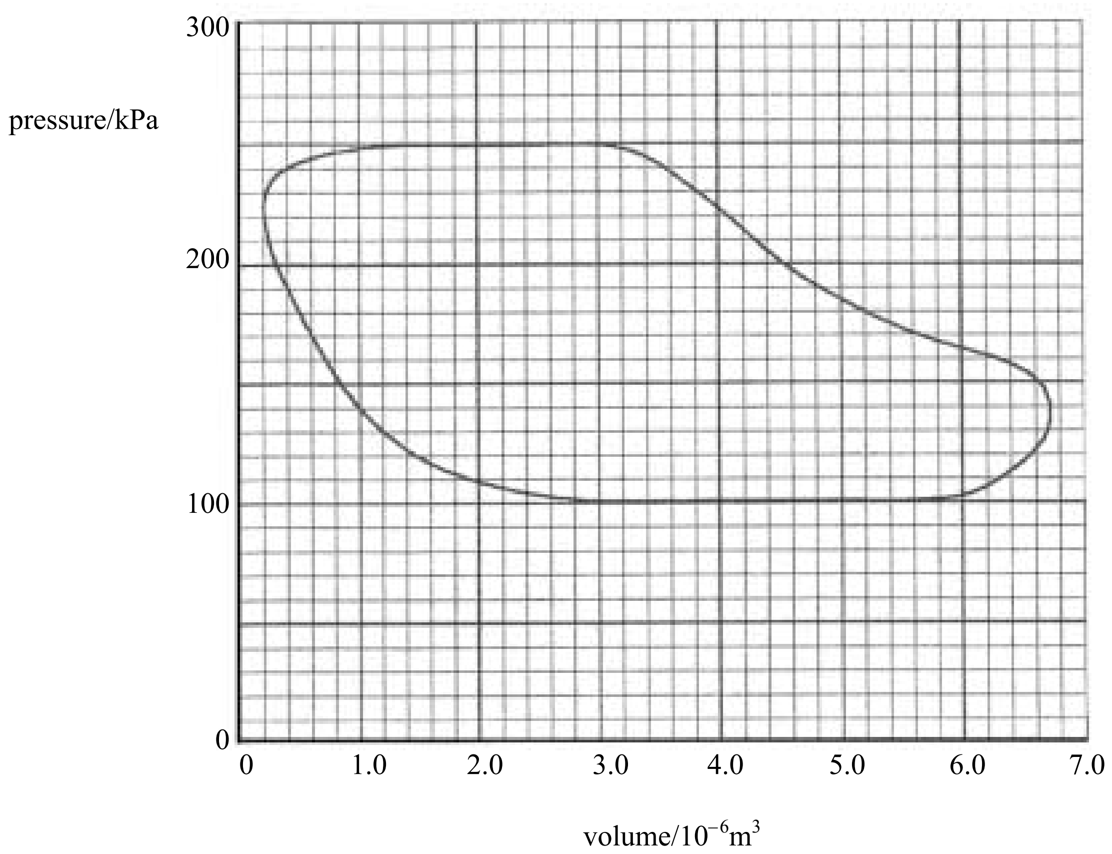
**Turn over**

**4** A small steam engine used for demonstrating energy transfers is fitted with sensors for monitoring the pressure and volume of the steam in its cylinder. The indicator diagram shows one cycle of pressure and volume changes taken when the engine was used to lift a load at a steady rate.




(a) Using information from the indicator diagram, together with the measured speed of the engine, the indicated power of the engine during the lifting operation was estimated to be 5.0 W. Show that this corresponds to an engine speed of about 450 cycles $min^{-1}$.

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*(5 marks)*

(b) During the lifting operation, a load of 42 N was lifted through a height of 1.2 m in a time of 12 s.

(i) Estimate the mechanical efficiency of the engine.

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(ii) Explain why the mechanical efficiency is not equal to 1.

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*(4 marks)*

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**TURN OVER FOR THE NEXT QUESTION**

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**5** A potter in an African village makes large clay pots on a stone wheel. The wheel rotates freely on a central bearing and is driven by the potter, who applies a tangential force repeatedly to its rim using his foot until the wheel reaches its normal working angular speed. He then stops driving and throws a lump of clay onto the centre of the wheel.

(a) The normal working angular speed of the wheel is $5.0\,\text{rad}\,\text{s}^{-1}$. The moments of inertia of the wheel and the clay about the axis of rotation are $1.6\,\text{kg}\,\text{m}^2$ and $0.25\,\text{kg}\,\text{m}^2$, respectively. When the clay is added, the angular speed of the wheel changes suddenly. The net angular impulse is zero.

Calculate the angular speed of the wheel immediately after the clay has been added.

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*(2 marks)*

(b) The potter now applies a tangential force to the rim of the wheel during one quarter of its revolution so that the angular speed returns to $5.0\,\text{rad}\,\text{s}^{-1}$. The wheel has a diameter of 0.62 m.

Calculate

(i) the angular acceleration of the wheel,

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(ii) the average tangential force which must be applied by the potter.

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*(4 marks)*

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**END OF QUESTIONS**