

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

**PHYSICS B
(ADVANCING PHYSICS)**



2863/01

Rise and Fall of the Clockwork Universe

Friday

20 JANUARY 2006

Morning

1 hour 15 minutes

Candidates answer on the question paper.

Additional materials:

- Data, Formulae and Relationships Booklet
- Electronic calculator

Candidate
Name

Centre
Number

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Candidate
Number

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TIME 1 hour 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers, in blue or black ink, in the spaces provided on the question paper.
- Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Show clearly the working in all calculations and give answers to only a justifiable number of significant figures.
- Do not write in the bar code. Do not write in the grey area between the pages.
- **DO NOT WRITE IN THE AREA OUTSIDE THE BOX BORDERING EACH PAGE. ANY WRITING IN THIS AREA WILL NOT BE MARKED.**

INFORMATION FOR CANDIDATES

- You are advised to spend about 20 minutes on Section A and 55 minutes on Section B.
- The number of marks is given in brackets [] at the end of each question or part question.
- There are four marks for the quality of written communication in Section B.
- The values of standard physical constants are given in the Data, Formulae and Relationships Booklet. Any additional data required are given in the appropriate question.

FOR EXAMINER'S USE		
Section	Max.	Mark
A	20	
B	50	
TOTAL	70	

This question paper consists of 16 printed pages.



Answer **all** the questions.

Section A

- 1 The nearest star, Proxima Centauri, is at a distance of 4.3 **light years** from Earth.

Calculate the distance to Proxima Centauri in metres.

$$c = 3.0 \times 10^8 \text{ m s}^{-1}$$

$$1 \text{ year} = 3.2 \times 10^7 \text{ s}$$

distance =m [2]



2 A process has an activation energy $E = 40 \text{ kJ mol}^{-1}$.

(a) Show that 40 kJ mol^{-1} is about $7 \times 10^{-20} \text{ J}$ per particle.

The Avogadro constant (number of particles per mole) = $6.0 \times 10^{23} \text{ mol}^{-1}$.

[1]

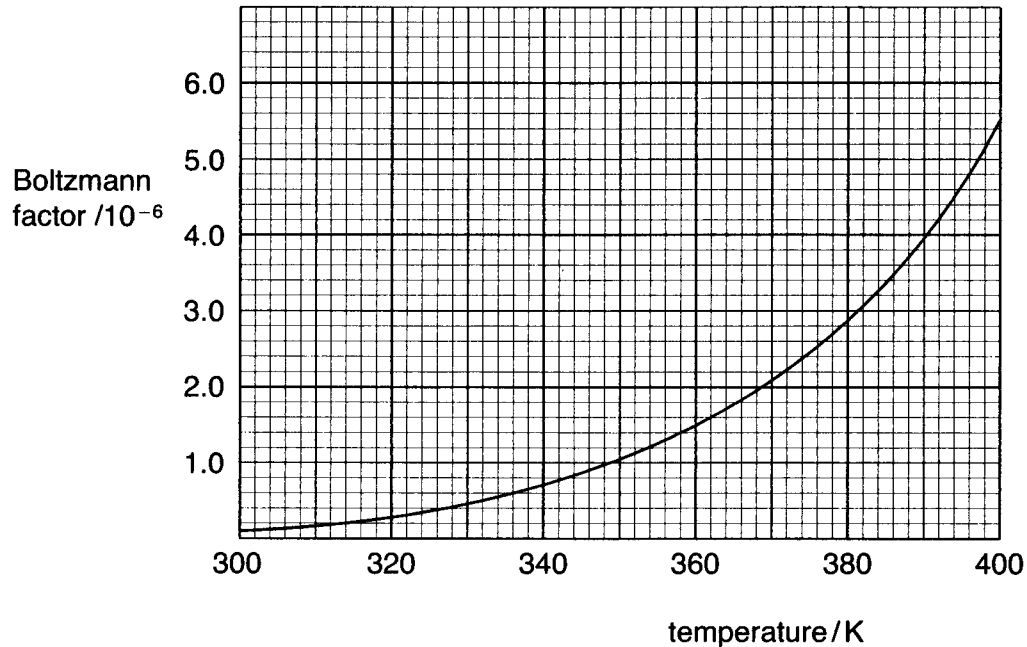


Fig. 2.1

(b) Fig. 2.1 shows the variation with temperature of the Boltzmann factor $f = e^{-E/kT}$ for this process.

(i) Describe how the Boltzmann factor varies with temperature over the range shown in the graph.

[2]

(ii) Sketch a second line on the graph showing how the Boltzmann factor would vary with temperature for a process with a slightly lower activation energy.

[1]

[Turn over]



- 3 An astronaut is using a 'manoeuvring unit' to propel herself during a spacewalk. A jet of nitrogen gas is ejected backwards to propel her forwards.

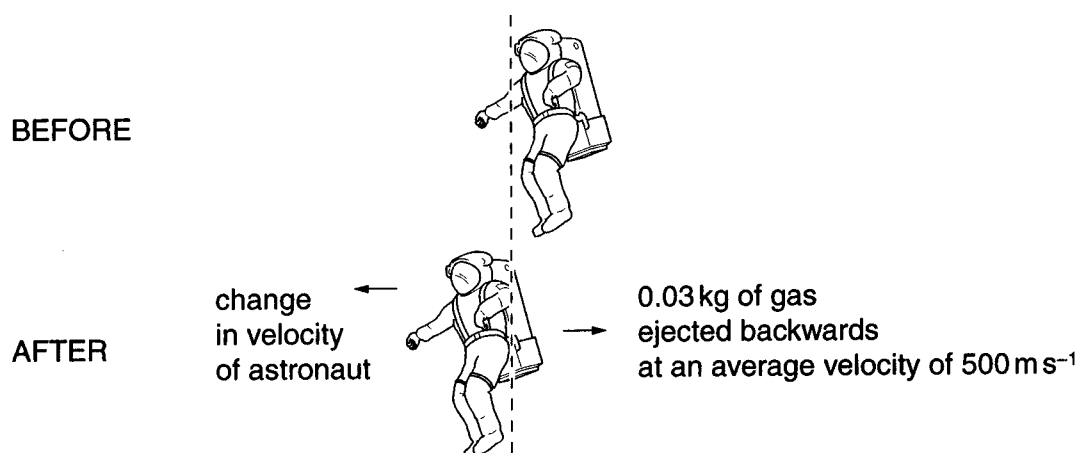


Fig. 3.1

The unit expels 0.03 kg of nitrogen gas at an average velocity of 500 m s⁻¹.

- (a) Calculate the momentum of the expelled gas.

momentum =kg m s⁻¹ [1]

- (b) Calculate the change in velocity of the astronaut.

Mass of astronaut and manoeuvring unit after ejection of gas = 110 kg.

change in velocity =m s⁻¹ [1]



4 A physics laboratory has a volume of 210 m^3 .

- (a) Calculate the mass of air in the laboratory.
density of air = 1.3 kg m^{-3}

mass of air =kg [1]

- (b) Calculate the energy needed to raise the temperature of the air in the room from 15°C to 22°C .

specific thermal capacity of air = $1000 \text{ J kg}^{-1} \text{ K}$

energy =J [2]

- (c) Give a reason why the actual energy to warm the room is likely to be greater than suggested by this simple calculation.

[1]

[Turn over



- 5 A student produces a simple model of radioactive decay using the following equation

$$\text{rate of decay of sample } \frac{\Delta N}{\Delta t} = -\lambda N$$

where N is the number of nuclei present
 λ is the decay constant
 Δt is a small interval of time
 ΔN is the number of nuclei decaying in time Δt .

The student chooses to set λ at 0.14 s^{-1} , the initial number of nuclei at 9.0×10^5 and the time interval Δt between calculations at 1.0 s . It is assumed that the rate of decay is constant over each time interval.

- (a) Show that according to this model the number of nuclei remaining after 1.0 s is about 7.7×10^5 .

[2]

- (b) The student uses the model to calculate the number of nuclei remaining at successive one second time intervals for a period of 8 seconds. These results are shown in Fig. 5.1.

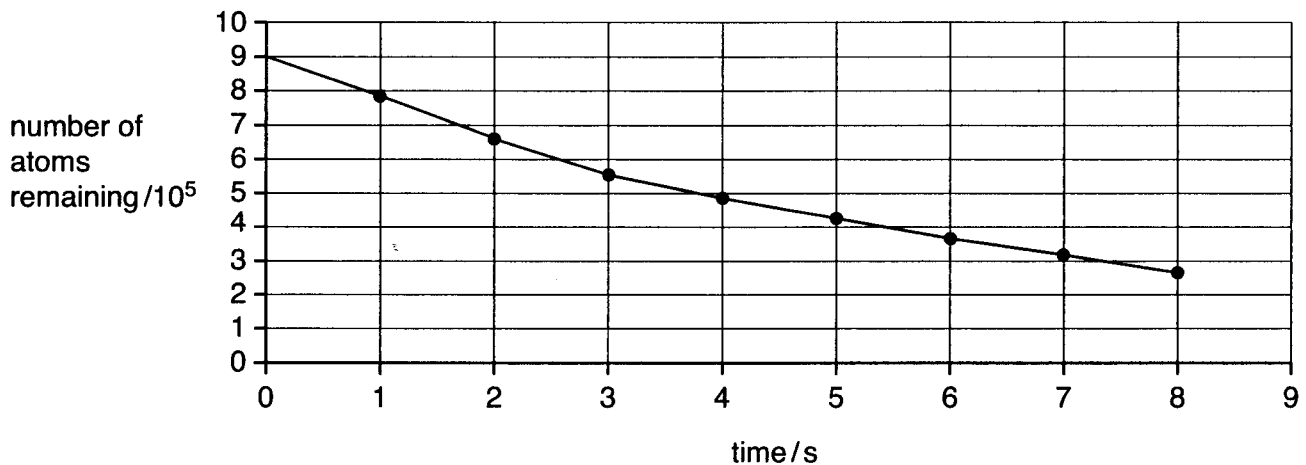


Fig. 5.1

- (i) Show on the graph that the model gives a half-life of about 4.6 s . [1]
- (ii) The actual half-life of an isotope with a decay constant of 0.14 s^{-1} is 5.0 s . Account for the inaccuracy of the model and suggest how the model could be improved to give a closer match to reality.

[2]



6 Fig. 6.1 shows a diagram of the interior of the Sun.

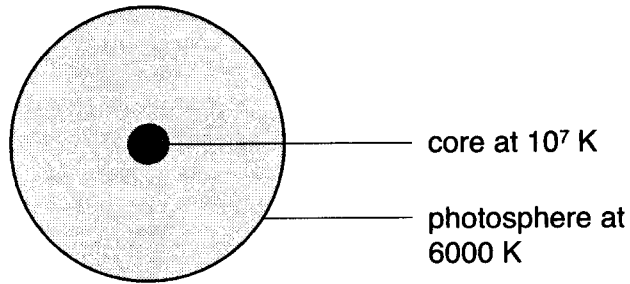


Fig. 6.1

(a) Estimate the typical energy of a gamma photon at a temperature of 10⁷ K.

the Boltzmann constant, $k = 1.4 \times 10^{-23} \text{ J K}^{-1}$

energy =J [1]

(b) Energy is transferred from the core at 10⁷ K to the photosphere at 6000 K by a process of absorption and re-emission of photons.

Use these data to show that for every one gamma photon in the core about 2000 visible photons are emitted in the photosphere.

[2]

[Section A Total: 20]

[Turn over



Section B

In this section, four marks are available for the quality of written communication.

- 7 The $4700\ \mu\text{F}$ capacitor shown in Fig. 7.1 is used as a part of a timing circuit.

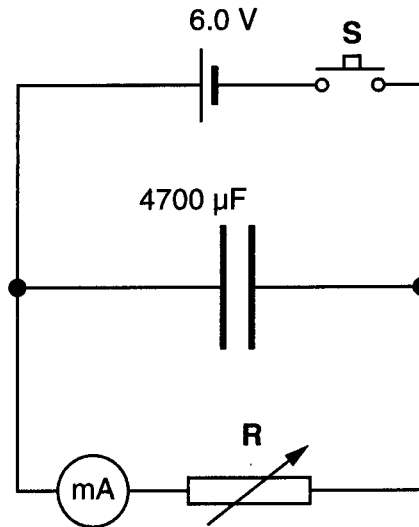


Fig. 7.1

The variable resistor **R** is initially set to a value of $12\ \text{k}\Omega$.
The timing sequence is started by closing and opening the switch **S**.

- (a) Whilst the switch **S** is closed, calculate

- (i) the charge stored by the capacitor

charge =C [1]

- (ii) the energy stored by the capacitor

energy =J [2]

- (iii) the current in **R**.

current =unit [2]

- (b) (i) Explain why the current will start to decrease as soon as **S** is opened.



(ii) Show that the time constant τ for this circuit is about 60 s.

[1]

(c) The experiment is repeated with the value of R reduced to $6.0 \text{ k}\Omega$ from its previous value of $12 \text{ k}\Omega$.

State the new values of

(i) the current whilst the switch is closed

current = [1]

(ii) the time constant.

time constant = [1]

(d) With R set at $6.0 \text{ k}\Omega$, a student briefly closes the switch S every 10 seconds. The voltage across the capacitor varies as shown in Fig. 7.2.

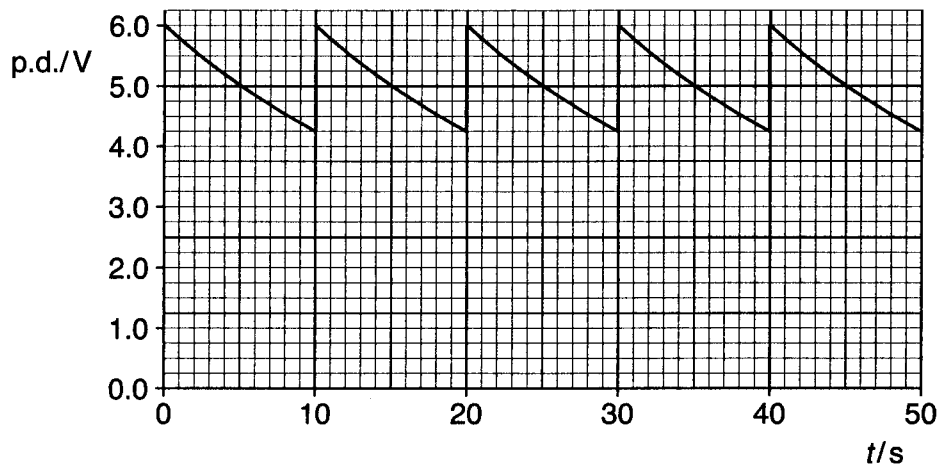


Fig. 7.2

State and explain **two** features of the graph.

feature 1:

explanation:

feature 2:

explanation:

[4]

[Total: 14]

[Turn over

