OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2826/01

Unifying Concepts in Physics

Monday **27 JANUARY 2003** Morning 1 hour 15 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator

Candidate Name	Centre Number	Candidate Number

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 the spaces on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	10	
2	20	
3	22	
4	8	
TOTAL	60	

This question paper consists of 14 printed pages and 2 blank pages.

SP SJF2652/PW S33781/6

[Turn over

Data

speed of light in free space,	$c = 3.00 \times 10^8\ \text{m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \text{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \text{J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
molar gas constant,	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
acceleration of free fall,	$g = 9.81\ \text{m s}^{-2}$

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
refractive index,	$n = \frac{1}{\sin C}$
capacitors in series,	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
capacitor discharge,	$x = x_0 e^{-t/CR}$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
radioactive decay,	$x = x_0 e^{-\lambda t}$
	$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$
critical density of matter in the Universe,	$\rho_0 = \frac{3H_0^2}{8\pi G}$
relativity factor,	$= \sqrt{(1 - \frac{v^2}{c^2})}$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10 \lg \left(\frac{I}{I_0}\right)$

For Examiner's Use

Answer **all** the questions.

1 (a) Using a digital car clock, which gives the time to the nearest minute, a passenger times a journey of 80 km on a motorway, measured from a map. At the start, the clock reading was 10 hours 6 minutes and at the finish it was 10 hours 54 minutes.

(i) What are the maximum and the minimum possible times for the journey?

maximum time = ... minutes

minimum time = ... minutes
[2]

(ii) Calculate the corresponding minimum and maximum average speeds for the journey in $km\,h^{-1}$.

minimum average speed = ... $km\,h^{-1}$

maximum average speed = ... $km\,h^{-1}$
[2]

(iii) State the average speed, x, of the car, and the possible uncertainty, y, in the form $x \pm y$.

.... $km\,h^{-1}$ [1]

(iv) State the uncertainty in the answer to **(iii)** as a **percentage** uncertainty.

percentage uncertainty = ... % [1]

For Examiner's Use

(b) For the same journey, discuss **two** ways in which the average speed for the journey can be measured more accurately.

(i) ....

....

....

(ii) ....

....

.... [4]

[Total: 10]

[Turn over

For Examiner's Use

2 (a) What is meant by the *internal energy* of an ideal gas?

....

.... [2]

(b) Assume argon gas at a temperature of 300 K behaves ideally. An atom of argon gas has mass 6.6×10^{-26} kg.

(i) Show that 0.020 kg of argon contains 3.0×10^{23} atoms.

[2]

(ii) The average speed of an argon atom at this temperature is 440 m s^{-1}. Determine the kinetic energy of an argon atom travelling at this speed.

kinetic energy = ... J [2]

(iii) The kinetic energy of an alpha particle from a radioactive source is 4.3 MeV. Calculate the ratio of the kinetic energy of the alpha particle to the kinetic energy of the argon atom in (ii).

ratio = ... [3]

For Examiner Use

(c) Not all the argon atoms in the gas in **(b)** have the same speed. This is shown in a histogram, Fig. 2.1.

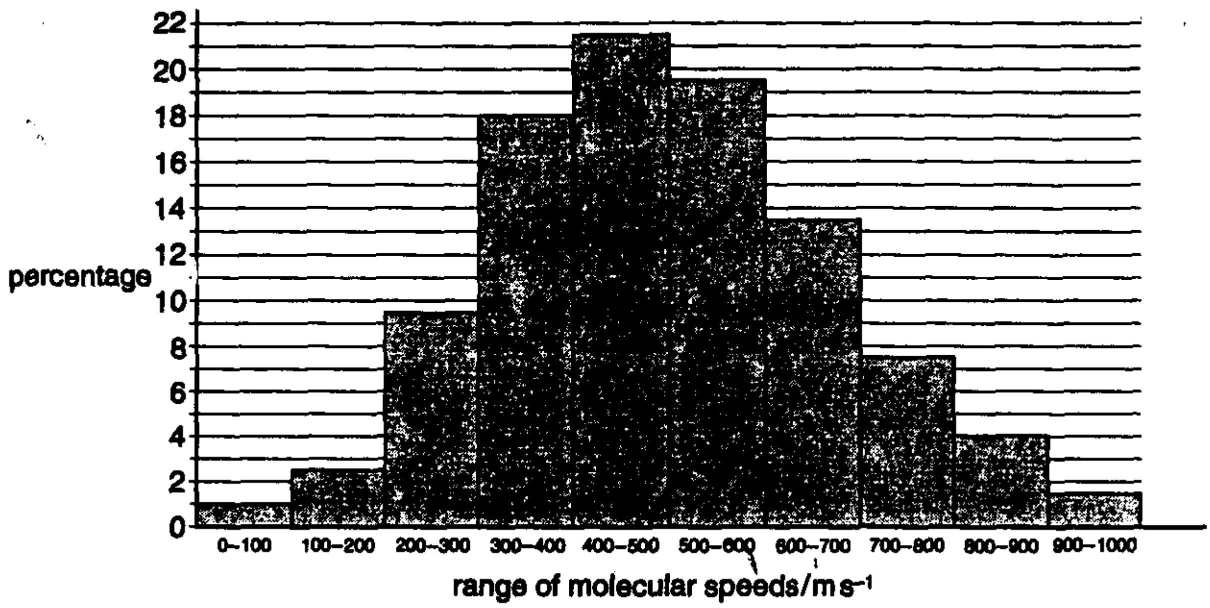

Fig. 2.1

The height of each column is equal to the percentage of atoms with speeds falling within the range given at the bottom of the column. For example, 18% of the atoms have speeds between 300 m s^{-1} and 400 m s^{-1}. Answer the following questions about the argon sample containing 3.0×10^{23} atoms.

(i) Show that the number of atoms in the sample having speeds between 500 m s^{-1} and 600 m s^{-1} is about 6×10^{22}.

[1]

(ii) Show that about 10^{22} atoms have speeds less than 200 m s^{-1}.

[1]

(iii) Find the total percentage of all the columns shown in the histogram and use your answer to find the total number of atoms with speeds greater than 1000 m s^{-1}.

number of atoms = ... [2]

[Turn over

For Examiner's Use

(iv) Approximately what percentage of atoms are travelling at more than twice the average speed of 440 m s^{-1}?

percentage of atoms = ... % [3]

(d) Illustrate, by drawing a line on Fig. 2.2, how the outline of the histogram would change if the temperature of the argon were increased. [2]

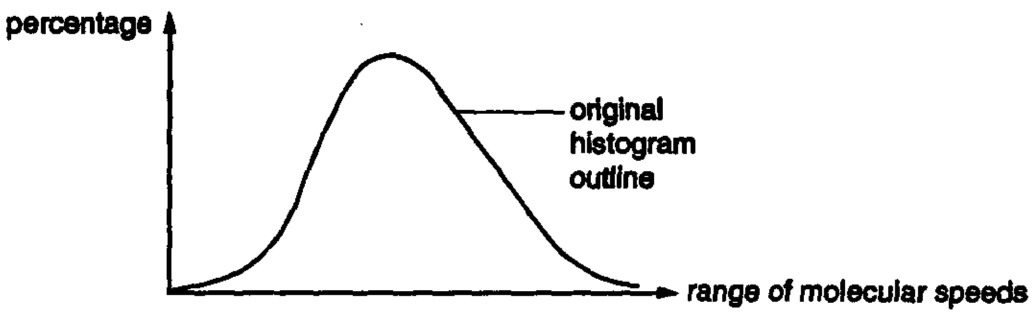

Fig. 2.2

(e) Describe how the behaviour of any substance, solid, liquid or gas, is affected considerably by the number of high speed atoms which it contains.

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.... [2]

[Total: 20]

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TURN OVER FOR QUESTION 3

Fig. 3.1

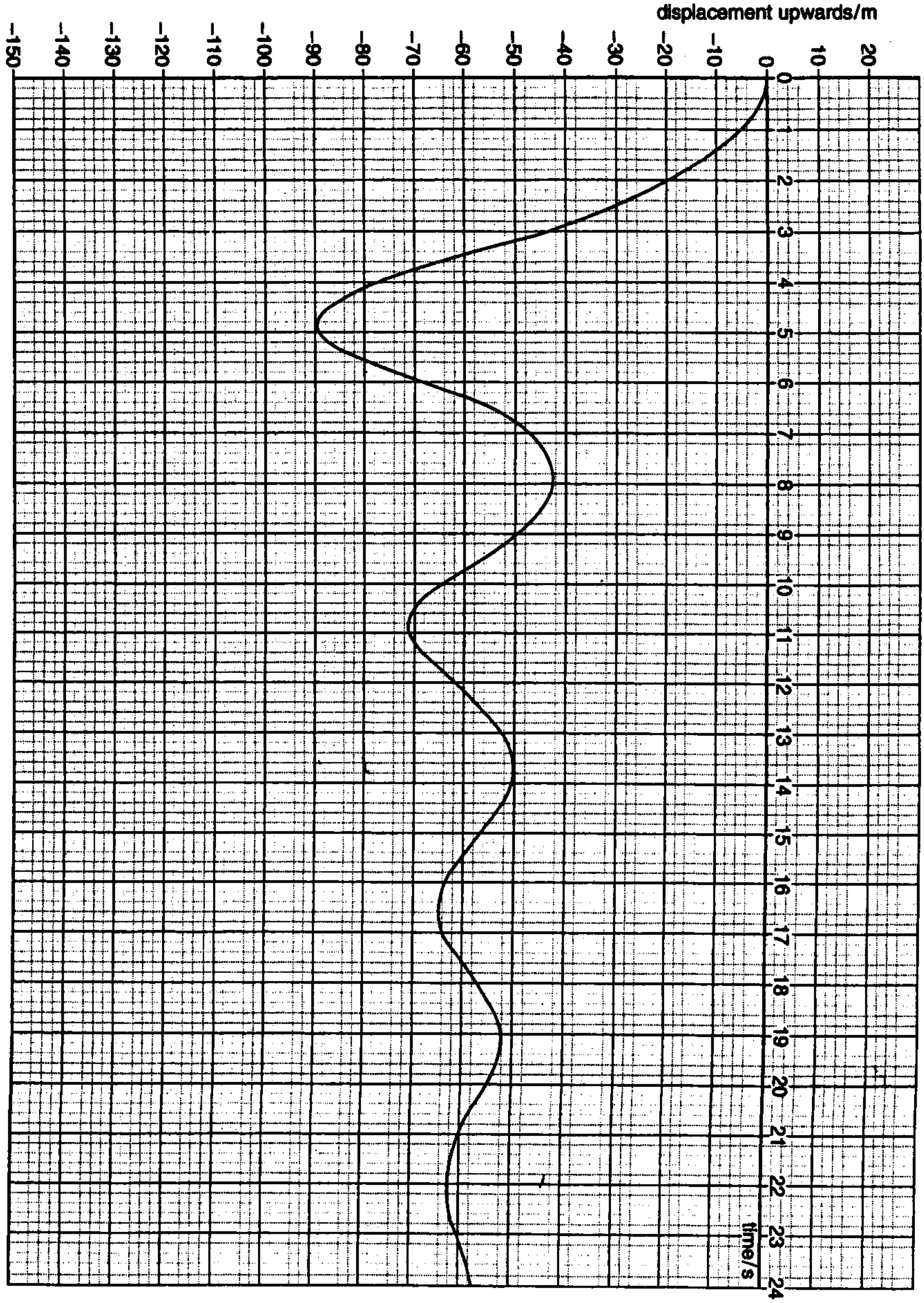
displacement upwards/m
−150 −140 −130 −120 −110 −100 −90 −80 −70 −60 −50 −40 −30 −20 −10 0 10 20
time/s
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Fig. 3.1

For Examiner's Use

3 When a person does a bungee jump, a video is often taken to record the event. From one such video of a jump down into the Zambezi Gorge, data was used to enable the displacement-time graph of Fig 3.1 to be plotted.

(a) What can be determined from the gradient of a displacement-time graph?

.... [1]

(b) Use Fig. 3.1 to

(i) estimate the time at which the jumper is falling at maximum speed

time = ... s [1]

(ii) calculate the maximum speed.

maximum speed = ... m s^{-1} [2]

(c) On Fig. 3.2, make a sketch of how the velocity changes

(i) during the first 3.2 s when the jumper is in free fall [2]

(ii) between 3.2 and 8.0 s. [2]

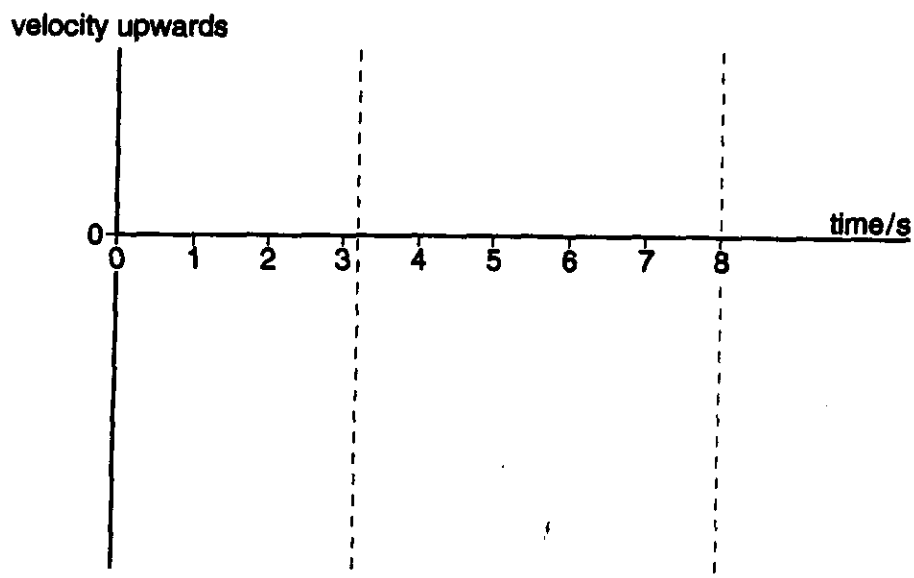

Fig. 3.2

[Turn over

(d) During the fall, there is a transfer of energy from gravitational potential energy to kinetic energy and elastic potential energy as shown in the table. Numbers accurate to two significant figures are used throughout.

distance of fall / m	gravitational P.E. / J	elastic P.E. / J	kinetic energy / J
0	54 000	0	0
20	42 000	0	
40	30 000	0	24 000
50 (unstretched length)	24 000		
59 (equilibrium position)			
90 (bottom)	0		

Assume frictional energy losses are negligible.
Weight of the jumper = 600 N.
Unstretched length of elastic rope = 50 m.
Assume the elastic rope obeys Hooke's Law with a spring constant equal to $67.5\,N\,m^{-1}$.

Complete the table. [9]

(e) After bouncing several times, the jumper ends up (upside down) in equilibrium. Explain what is meant by equilibrium. Suggest and explain things that could be done to reach equilibrium more rapidly.

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.... [5]

[Total: 22]

TURN OVER FOR QUESTION 4.

For Examiner's Use

4 (a) Explain the meaning of the term *field* as it is used in physics.

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.... [2]

(b) Choose **two** different fields. For each field describe a practical application, making use of a field diagram. Explain what can be deduced from each diagram.

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[Total: 8]