RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) 2865/01

Advances in Physics

Monday **27 JUNE 2005** Afternoon 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Insert (Advance Notice Article for this question paper)
Data, Formulae and Relationships Booklet
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 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 provided on the question paper.
- 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.

INFORMATION FOR CANDIDATES

- Section A (questions 1–7) is based on the Advance Notice article, a copy of which is included as an insert. You are advised to spend about 60 minutes on Section A.
- 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 on this paper.
- 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		
Qu	**Max.**	**Mark**
1	7	
2	8	
3	10	
4	10	
5	4	
6	9	
7	9	
8	14	
9	15	
QWC	4	
TOTAL	90	

This question paper consists of 19 printed pages, 1 blank page and an insert.

Answer **all** the questions.

Section A

The questions in this section are based on the Advance Notice article.
You are advised not to spend more than 60 minutes on this section.

1 This question compares electrical, magnetic and water circuits (lines 8–16 and Fig. 1 in the article).

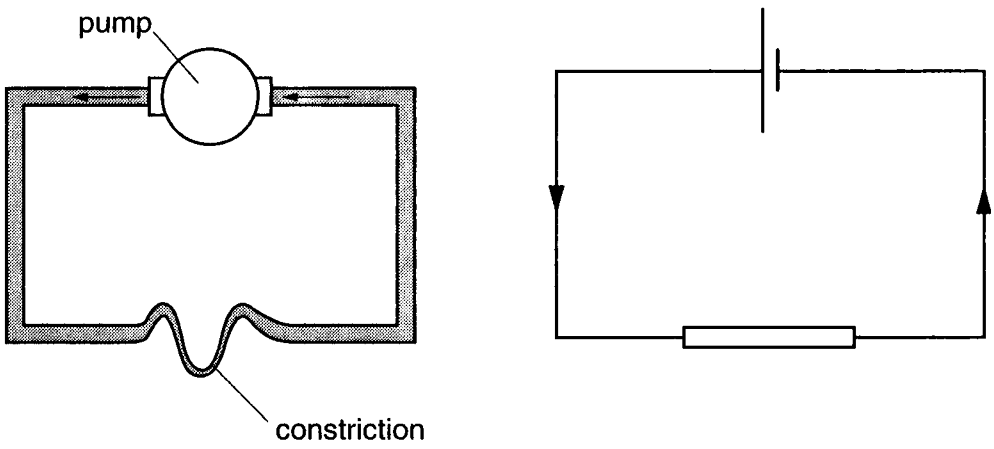

Fig. 1.1

(a) Fill in the spaces in the table below to show the electrical quantities modelled by those in the water circuit.

water circuit	electrical circuit
pressure difference	
water	
rate of flow of water	

[3]

(b) Suggest changes you could make to the water circuit to model these changes in the electrical circuit

(i) using a battery of greater emf

[1]

(ii) using a resistor of larger resistance.

[1]

For Examiner's Use

(c) Fig. 1.2 below shows an electromagnet lifting a steel object.

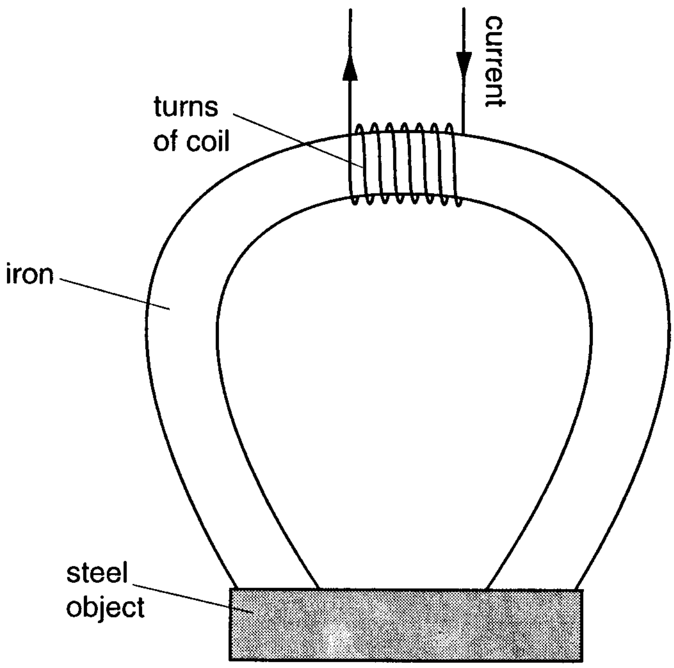

Fig. 1.2

Fill in the spaces in the table below to show the magnetic quantities modelled by those in the water circuit.

water circuit	magnetic circuit
pressure difference	
rate of flow of water	

[2]

[Total: 7]

[Turn over

For Examiner's Use

2 This question is about the Titius-Bode Law and Kepler's Laws (lines 35–69 and Fig. 3 in the article).

The Titius-Bode Law can be written as

$$R = 0.40 + 0.30 \times 2^n$$

where R is measured in Astronomical Units (the mean radius of the Earth's orbit).

(a) This table shows predicted values of R for different values of n.

planet	n	Titius-Bode Law R/AU	Actual mean R/AU
Mercury		0.40	0.39
Venus	0	0.70	0.72
Earth	1	1.00	1.00
Mars	2	1.60	1.52
Ceres (an asteroid)	3	2.80	2.80
Jupiter	4	5.20	5.20
Saturn	5		9.54
Uranus	6	19.6	19.2
Neptune	7	38.8	30.1

(i) Show that the value of R for Saturn given by the equation is close to the actual value of 9.54 AU.

[2]

(ii) The value of n for the planet Mercury is not given. Suggest why it is difficult to model the orbit of Mercury with the equation $R = 0.40 + 0.30 \times 2^n$.

[2]

For Examiner's Use

(b) The Titius-Bode 'Law' was published in 1770. The following astronomical discoveries were made after that date.

discovery	date
Uranus	1781
Ceres	1801
Neptune	1846

Explain why the article states 'Although the Titius-Bode Law seemed promising for a while, it was eventually discredited.' (line 66 in the article)

[2]

(c) The following analysis shows how Newton's Laws, applied to a circular orbit, result in Kepler's Third Law.

expression A **expression B** **expression C**

$$\frac{v^2}{R} = \frac{GM}{R^2} \quad \text{so} \quad v^2 = \frac{GM}{R}$$

expression D

$$\text{but } v = \frac{2\pi R}{T}$$

expression E

$$\text{so } v^2 = \frac{4\pi^2 R^2}{T^2} = \frac{GM}{R} \quad \text{and} \quad \frac{R^3}{T^2} = \frac{GM}{4\pi^2}$$

(i) Which **one** of expressions A–E gives the gravitational field strength g acting at this orbit?

....[1]

(ii) Which **one** of expressions A–E gives the centripetal acceleration of the orbiting body?

....[1]

[Total: 8]

[Turn over

For Examiner's Use

3 This question is about models of the atom (lines 71–101 and Fig. 4 in the article).
J J Thomson and Ernest Rutherford both suggested models of the atom.

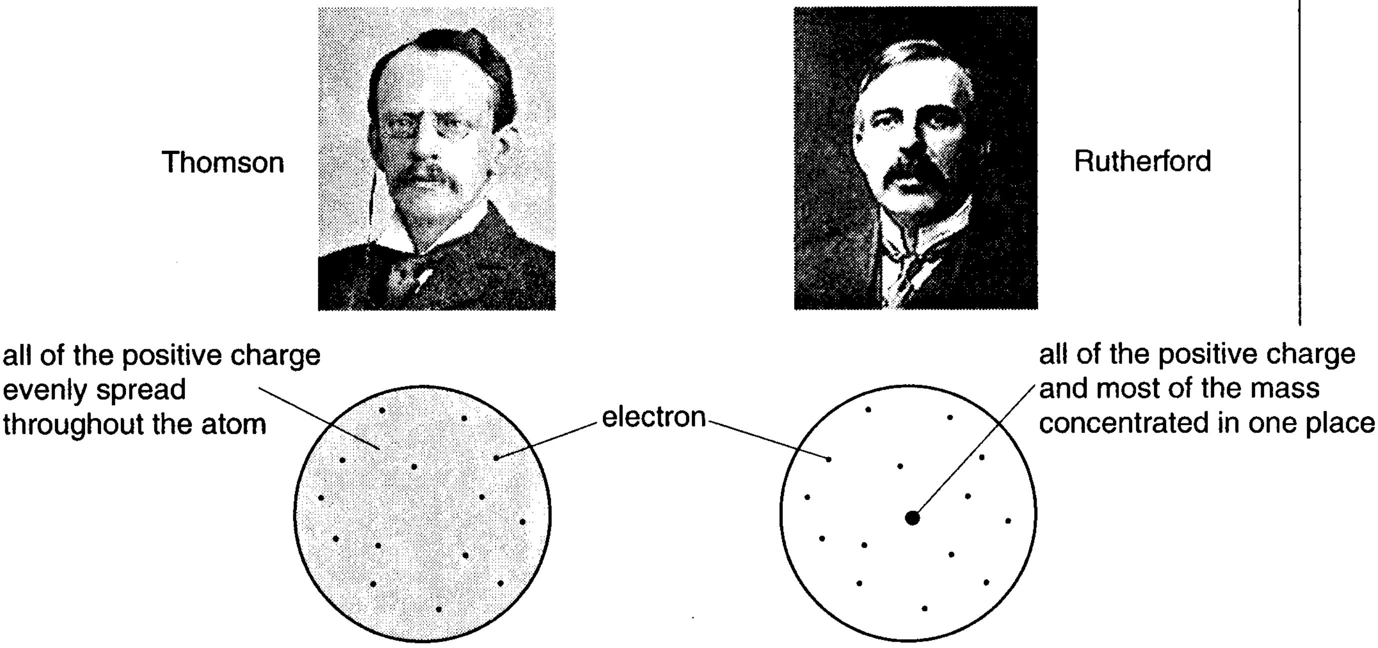

Fig. 3.1

(a) Put a tick (✓) or cross (✗) in **each** space in this table to show which phenomena could (✓) or could not (✗) be consistent with the simple models shown above.

phenomenon	Thomson model	Rutherford model
When alpha particles are directed at gold foil, some are deflected through very large angles.		
Metals illuminated with ultraviolet light give off electrons.		

[2]

(b) An alpha particle of energy 6.5 MeV approaches a gold nucleus head-on and is brought to a stop, as shown in Fig. 3.2.

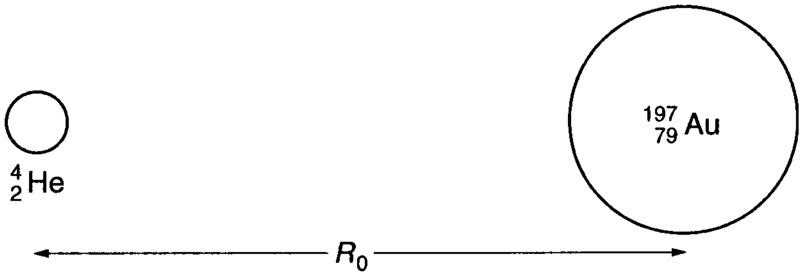

Fig. 3.2

(i) Show that 6.5 MeV is about 1 pJ.
$e = 1.6 \times 10^{-19}$ C

[2]

(ii) Calculate the closest distance of approach R_0 of a 6.5 MeV alpha particle to a nucleus of gold ($^{197}_{79}Au$) as shown in Fig. 3.2 opposite.

$$k = \frac{1}{4\pi\varepsilon_0} = 9.0 \times 10^9\,\mathrm{N\,m^2\,C^{-2}}$$

$$e = 1.6 \times 10^{-19}\,\mathrm{C}$$

distance .... m [3]

(iii) State **one** assumption that must be made in order to calculate this distance.

[1]

(c) When alpha particles are 'fired' at beryllium, neutrons are produced, as shown in Fig. 3.3.

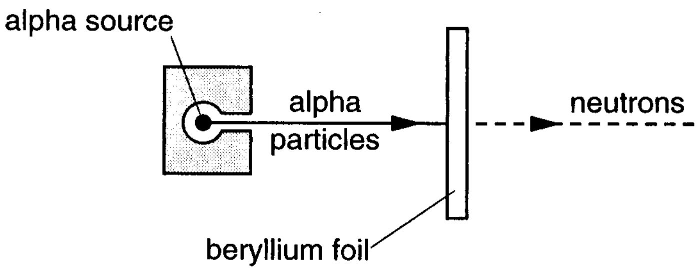

Fig. 3.3

The reaction producing the neutrons is

$$^{9}_{4}\mathrm{Be} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{n} + {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{C}$$

Complete the nuclear equation by filling in the appropriate nucleon and proton numbers in the spaces above. [2]

[Total: 10]

For Examiner's Use

4 This question is about using a numerical approach to model radioactive decay (lines 117–134 in the article).

(a) The radioactive decay equation $\frac{dN}{dt} = -\lambda N$ is used in the model in the form

$$\Delta N = -\lambda N \times \Delta t.$$

(i) State what each of the variables represents in this equation.

ΔN	
λ	
N	
Δt	

[4]

(ii) Explain how the model would behave differently if the right-hand side had a plus and not a minus sign.

[1]

(b) In a computer simulation using this model, the following graph (Fig. 4.1) was obtained for a set of 1000 nuclei, each having a **one in five** chance of decaying each second.
In this model, $\Delta t = 0.1$ s.

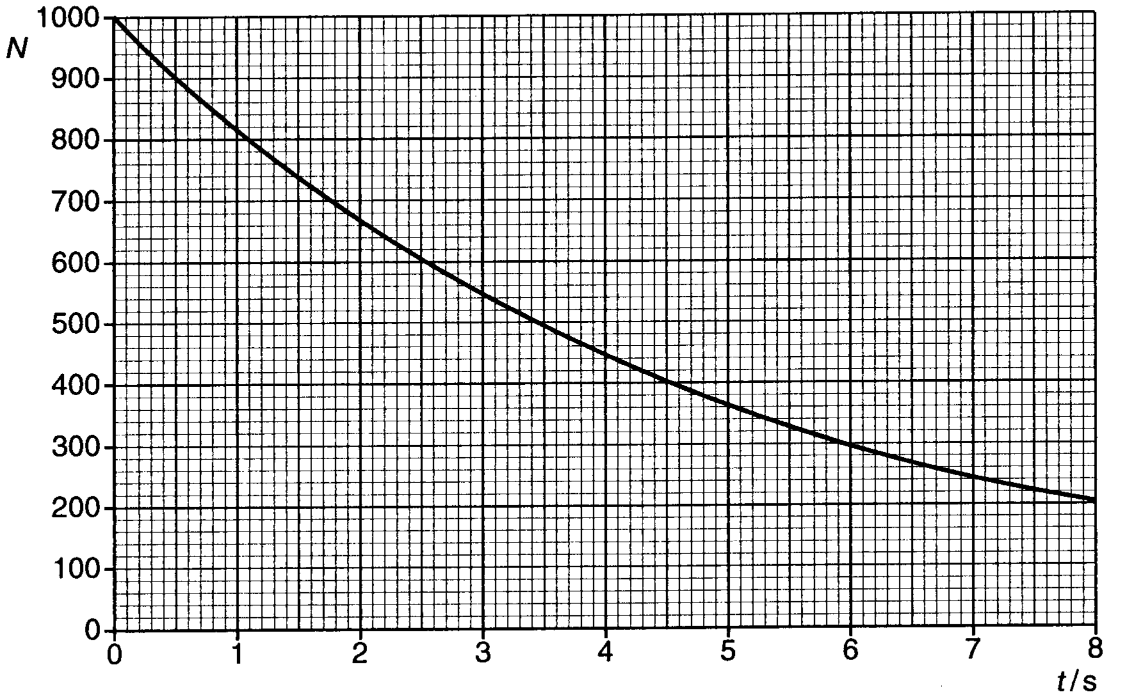

Fig. 4.1

Draw as accurately as you can on the graph the curve you would expect, again for a set of 1000 nuclei, but now with each having a **one in ten** chance of decaying each second.
[2]

(c) For many radioactive isotopes, 'parent' nuclei decay to give 'daughter' nuclei which are also unstable.

The equation which models the number of daughter nuclei, N_d, can be written as

ΔN_d = (number of decaying parent nuclei) – (number of decaying daughter nuclei)

where ΔN_d is the change in the number of daughter nuclei in the time interval concerned.

The graph below (Fig. 4.2) shows how the number of daughter nuclei, N_d, varies with time, starting with a pure sample of parent nuclei.

In this model, both parent and daughter nuclei have similar half-lives.

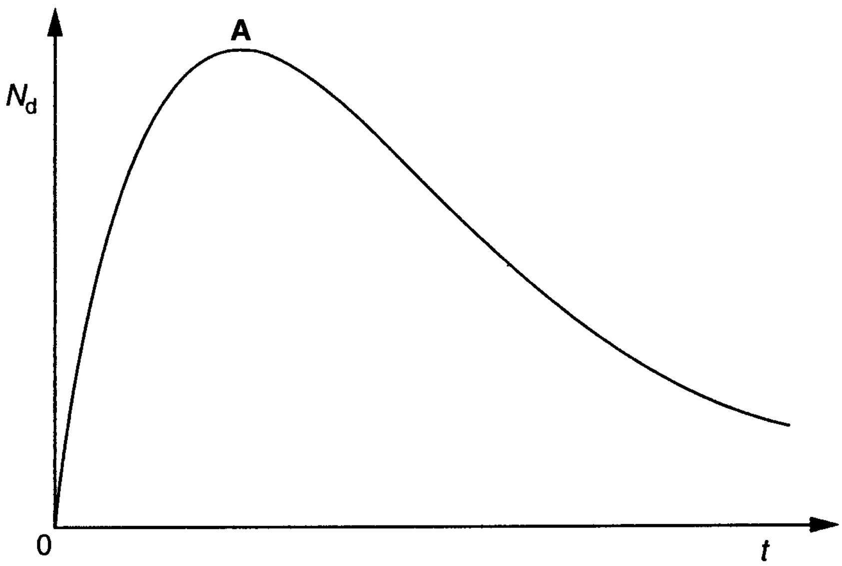

Fig. 4.2

(i) Explain why the graph rises rapidly between 0 and **A**.

[1]

(ii) The graph has a maximum at **A**. Explain what is happening at this time.

[2]

[Total: 10]

For Examiner's Use

5 This question is about using a computer object approach to model radioactive decay (lines 123–134 and Fig. 5 in the article).

Fig. 5.1 shows a graph that was obtained in a simulation using 25 computer 'nuclei'. In this model values were plotted every 2.0 s, and the chance of decay in 2.0 s was 2 in 5.

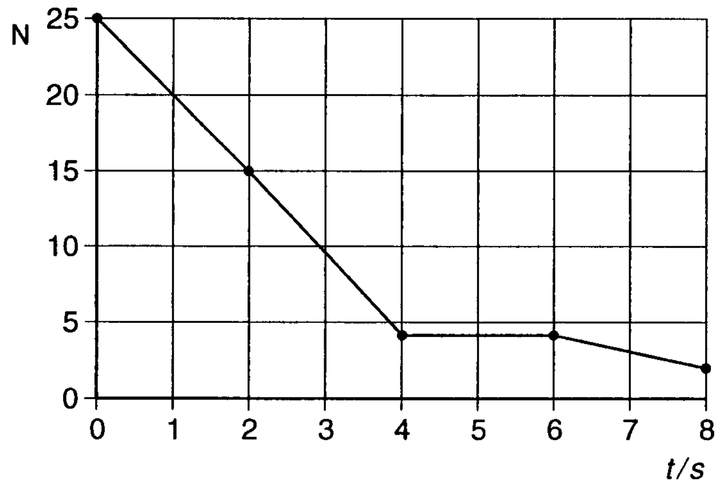

Fig. 5.1

(a) Explain why another run of the same model would be very unlikely to give exactly the same results as Fig. 5.1.

[2]

(b) Explain what features of Fig. 5.1 show that the results of the simulation are different from the solution of the equation $\frac{dN}{dt} = -\lambda N$.

[2]

[Total: 4]

For Examiner's Use

6 This question is about modelling the weather with the Unified Model (lines 136–149 and Figs. 6 & 7 in the article).

(a) Suggest **two** physical quantities describing the atmosphere which should be input into a climate model.

[2]

(b) Suggest how **one** of these physical quantities could be measured for different regions of the atmosphere.

[2]

(c) Explain the changes that have been made to improve the **resolution** of the Unified Model in recent years.

[3]

(d) The weather forecast for Great Britain is quite accurate for two or three days ahead. Suggest and explain **one** reason why accurate prediction for a week or more is not usually possible.

reason	explanation

[2]

[Total: 9]

[Turn over

7 This question is about changes in the atmosphere with height (lines 150–153 and Fig. 7 in the article).

Fig. 7.1 shows how atmospheric pressure varies with altitude. The dotted lines show the separate layers into which the atmosphere is divided for calculations in a computer model.

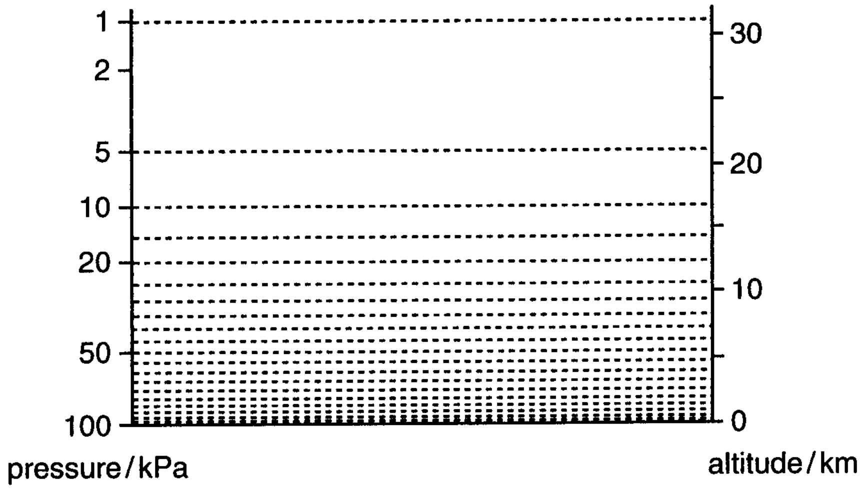

Fig. 7.1

(a) Explain how Fig. 7.1 above indicates that 'the density of the air decreases with height' (lines 151–152 in the article).

[2]

(b) It is suggested that atmospheric pressure varies exponentially with altitude. Use the data in Fig. 7.1 to test this.

test applied to data	result of the test

[2]

For Examiner's Use

(c) A simple model suggests that the Boltzmann factor $e^{-\frac{E}{kT}}$ describes how the atmosphere gets less dense with increase in altitude. Fig. 7.2 shows two levels in the atmosphere separated by a height *h*. *E* is the energy needed to lift a molecule between the two levels.

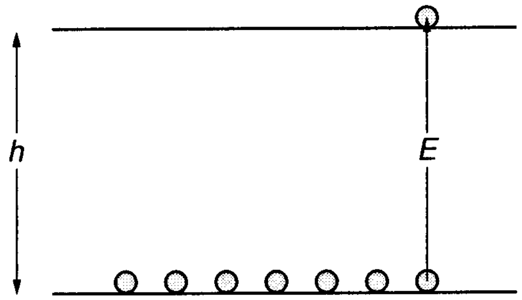

Fig. 7.2

(i) Show that the energy *E* needed to lift a molecule of mass 5.0×10^{-26} kg to a vertical height of 1.0 km above the Earth's surface is about 5×10^{-22} J.

$g = 9.8\ \text{N kg}^{-1}$

[1]

(ii) The fraction *f* of molecules at the lower level with enough energy to reach the level *h* above it, is

$$f = e^{-\frac{E}{kT}}$$

1 Show that the Boltzmann factor *f* for molecules separated vertically by 1.0 km is about 0.9 when the atmospheric temperature is 295 K.

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

[1]

2 Explain why this model suggests that only about 50% – 60% of the molecules have enough energy to reach a height of 5.0 km.

[2]

(iii) The actual variation of pressure with height does not follow the pattern predicted by this model through the whole atmosphere.
Suggest **one** reason why the model does not apply in practice.

[1]

[Total: 9]

[Turn over

Section B

8 This question is about electron beams in television tubes.

(a) A television tube is a simple particle accelerator, designed to give electrons sufficient energy to produce a bright picture on the screen. Fig. 8.1 shows a section through a simple electron gun in an evacuated TV tube.

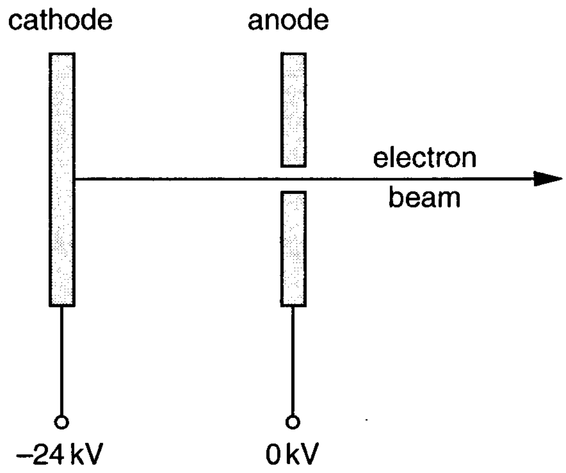

Fig. 8.1

(i) Draw on Fig. 8.1 **six** lines to represent the electric field in the space between the cathode and the anode. [2]

(ii) Show that an electron will have a kinetic energy of about 4×10^{-15} J as it reaches the anode when the p.d. between anode and cathode is 24 kV.

$e = 1.6 \times 10^{-19}$ C

[3]

(iii) If all the kinetic energy of the electron were converted to a single photon of electromagnetic radiation, show that its frequency would be about 6×10^{18} Hz.

$h = 6.6 \times 10^{-34}$ J s

[2]

For Examiner's Use

(iv) When each electron strikes the fluorescent chemicals on the TV screen, it does not emit a single high-energy photon. It emits a large number of photons of visible light. The wavelength of this visible light is 500 nm.

Calculate the maximum number of visible photons produced by each 4×10^{-15} J electron.

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

number = ... [3]

(b) An evacuated glass TV tube has to be carefully designed to withstand the large forces exerted by the atmosphere.

(i) Calculate the force that the screen has to support due to atmospheric pressure (1.0×10^5 Pa) if the dimensions of the screen are 0.50 m × 0.35 m.

force = ... N [2]

(ii) Explain, in terms of the momentum of gas molecules in the atmosphere, how the atmosphere exerts this force on the screen.

[2]

[Total: 14]

For Examiner's Use

9 This question is about mobile phone technology.

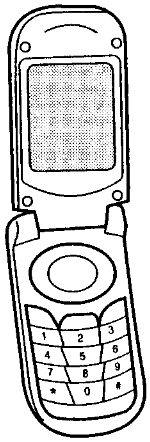

Fig. 9.1

(a) A typical phone battery has an emf of 3.6 volts and a capacity (the product of the current and time for which that current can be maintained) of 750 mA h (milliampere-hours).

(i) Assuming that the power drawn from the battery is 0.25 W, show that the current it delivers is about 70 mA.

[2]

(ii) Show that the charge flowing from the battery when it discharges completely is about 3000 C.

[2]

(iii) Calculate the maximum time for which the battery would last.

maximum time = ... h [2]

(iv) 0.25 W is actually the power of the electromagnetic radiation emitted by the mobile phone.
Explain why your answer to **(iii)** is likely to be an **overestimate**.

[1]

(b) The phone samples the speech waveform at 8 kHz and each sample is represented by an 8 bit binary number.

(i) Calculate the number of bits that have to be transmitted per second.

number of bits = ... [1]

(ii) Suggest why a lower sampling rate is not used to reduce the required bit rate.

[1]

(c) Explain why text messaging requires much less information to be transmitted than does voice communication.

[2]

(d) Following concerns about potential health hazards associated with the electromagnetic waves emitted from mobile phones, the Government has established a maximum Specific Absorption Rate of $2\,\text{W kg}^{-1}$ in the head while using the phone.

(i) Calculate the initial rate of temperature increase when 1 kg of water absorbs radiation at this rate.

specific heat capacity of water, $c = 4200\,\text{J kg}^{-1}\,°\text{C}^{-1}$

rate of temperature increase = ... [2]

(ii) Although the human body consists largely of water, the initial rate of rise of temperature of the brain is likely to be different from this value.
Suggest why this might be the case.

[1]

(iii) If the brain absorbed **gamma radiation** at a rate of $2\,\text{W kg}^{-1}$, a dangerously high dose of 1 sievert would be received in 0.5 s.

Suggest why mobile phones do not present such a high risk.

[1]

[Total: 15]

Quality of Written Communication [4]

END OF QUESTION PAPER

Copyright Acknowledgements:

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Photo of Ernest Rutherford from www.pbs.org