Oxford Cambridge and RSA

A Level Physics A

H556/03 Unified physics

Practice paper – Set 2

Time allowed: 1 hour 30 minutes

You must have:
- the Data, Formulae and Relationship booklet

You may use:
- a scientific calculator
- a ruler (cm/mm)

First name	
Last name	

Centre number						Candidate number				

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*****).
- This document consists of **16** pages.

Answer **all** the questions

1 This question is about helium in the atmosphere of the Earth.

Experiment shows that most of the Earth's atmosphere is contained within a very thin shell around the surface of the Earth. Less than 0.0001% of this is helium.

(a) Assume that the Earth's atmosphere has a constant density ρ of 1.3 kg m^{-3}. The atmospheric pressure at sea level is 1.0×10^5 Pa.
Show that the depth of the atmosphere under these conditions would be about 8 km.

[2]

(b) The height of the atmosphere is negligible compared with the radius R of the Earth.

(i) Show that the minimum speed v_E required for an atom or molecule to escape from the top of the Earth's atmosphere is given by the expression

$$v_E = \sqrt{2gR}\,.$$

[3]

(ii) The radius R of the Earth is 6.4×10^6 m. Calculate this escape speed v_E.

v_E = ... m s^{-1} **[1]**

(iii) Calculate the temperature T in kelvin required at the top of the Earth's atmosphere for the root mean square speed $c_{r.m.s.}$ of the helium atoms there to equal this escape speed.

Molar mass of helium = 0.004 kg mol^{-1}

T = ... K **[3]**

(iv) Fig. 1 shows the distribution of the speeds of the atoms of an ideal gas.

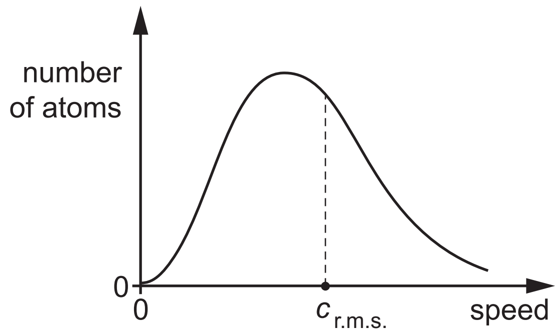

Fig. 1

Use your knowledge of the kinetic theory of gases to describe the shape of this distribution and explain why some helium is able escape from the Earth.

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(v) Over a very long period of time all of the helium should have escaped from the Earth. Suggest why there is still a small amount of helium, about 0.0001%, in the Earth's atmosphere.

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2 A student designs an investigation to learn more about an old instrument called a hot wire ammeter. A fine resistance wire stretched between two retort stands sags when heated by the current being measured. This sag is converted into a reading on a non-linear scale.

A current-carrying wire is clamped at each end as shown in Fig. 2.1.

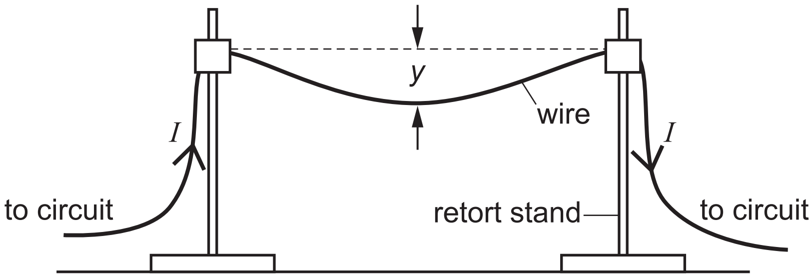

Fig. 2.1

The deflection y at the centre of the wire is measured for various currents I in the wire.
It is suggested that y and I are related by the equation

$$y = aI^b$$

where a and b are constants. This equation can also be written as

$$\lg y = \lg a + b \lg I.$$

(a) A graph is plotted of lg y on the y-axis against lg I on the x-axis. State expressions for the gradient and y-intercept in terms of a and b.

gradient = ...

y-intercept = ...
[1]

(b) For different values of the current I, the vertical deflection y is recorded. A table of results is shown with further columns giving values of lg (I/ 10^{-2} A) and lg (y/mm), including the absolute uncertainties.

I / 10^{-2} A	y / mm	lg (I / 10^{-2} A)	lg (y / mm)
50	2.6 ± 0.2		
60	3.4 ± 0.2	1.78	0.53 ± 0.03
70	4.4 ± 0.2	1.85	0.64 ± 0.02
80	5.4 ± 0.2	1.90	0.73 ± 0.02
90	6.6 ± 0.2	1.95	0.82 ± 0.01
95	7.2 ± 0.2	1.98	0.86 ± 0.01

(i) Complete the missing values in the table, including the absolute uncertainty for lg (y/mm). **[2]**

(ii) Fig. 2.2 shows the axes for a graph of lg (y/mm) on the y-axis against lg (I/10^{-2} A) on the x-axis. The last four points have been plotted including error bars for lg (y/mm). By plotting the two remaining points, complete the graph. Draw a line of best fit. **[2]**

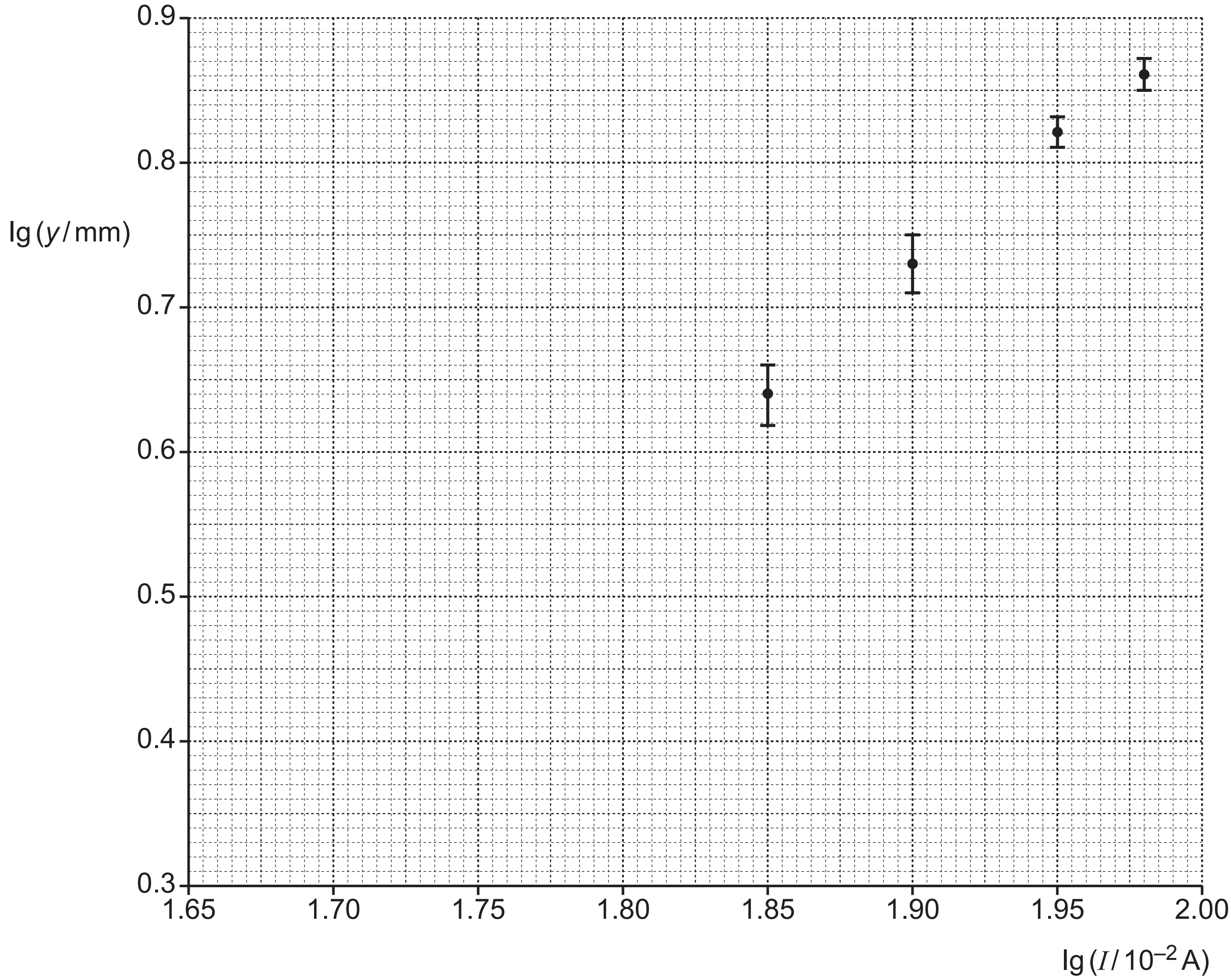

Fig. 2.2

(c) (i) Use the line of best fit through the data points in Fig. 2.2 to determine numerical values of

1 b

b = ... **[1]**

2 a.

a = ... **[2]**

(ii) Determine the absolute uncertainty in the value of b.

uncertainty in b = ± .... **[2]**

3 Fig. 3.1 shows a simple representation of a hydrogen iodide molecule. It consists of two ions $^{1}_{1}H^{+}$ and $^{127}_{53}I^{-}$, held together by electric forces.

Fig. 3.1

(a) **(i)** Draw on Fig. 3.1 a minimum of five lines to show the electric field pattern between the ions. **[2]**

(ii) The charge on each ion has a magnitude e of 1.6×10^{-19} C. The ions are to be treated as point charges 5.0×10^{-10} m apart. Calculate the magnitude of the resultant electric field strength E at the **mid-point** between the ions.

E = ... $N C^{-1}$ **[4]**

(b) Fig. 3.2 shows a simple mechanical model of the molecule consisting of two unequal masses connected by a spring of force constant k and negligible mass. The ions oscillate in simple harmonic motion when disturbed.

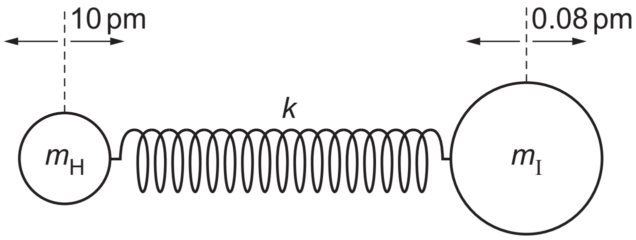

Fig. 3.2

(i) The approximate acceleration a of the hydrogen ion, mass m_H, is given by the equation

$$a = -\left(\frac{k}{m_H}\right)x$$

where k is the force constant of the spring and x is the displacement of the ion.
The ions oscillate with a frequency of 6.6×10^{13} Hz. The mass m_H is 1.7×10^{-27} kg.
Show that the value of k is about $300\,\text{N}\,\text{m}^{-1}$.

[3]

(ii) Use Newton's laws of motion and a requirement for simple harmonic motion to explain why the amplitude of oscillation of the iodine ion, mass m_I, is about 0.08 pm when the amplitude of oscillation of the hydrogen ion is about 10 pm.

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4 This question is about the brightest wavelength (590 nm) of light from a sodium lamp.

(a)* A student is to measure this wavelength by the double-slit method. The lamp, a single slit, a double slit and a clear glass screen are to be set up perpendicular to a common centre line as shown in Fig. 4.

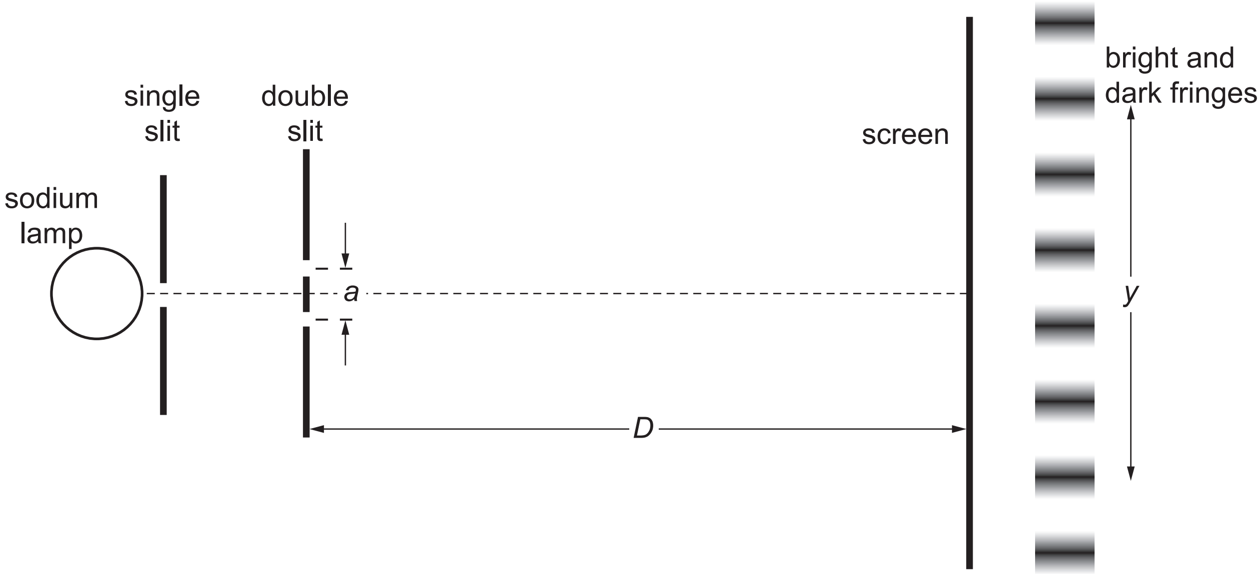

Fig. 4 (not to scale)

A pattern of bright and dark fringes should then be observable through the screen. The screen has millimetre rulings along it. The slit separation *a* is about 0.5 mm and can be measured using a travelling microscope, having a vernier scale to 0.05 mm. The student is also given two 1 metre rulers and a magnifying glass.

The measurements required to calculate the wavelength in the experiment are *a*, *D* and *y* on Fig. 4.

- Explain how the student measures *D* and *y* using the apparatus provided.
- State the uncertainty expected in each measurement and how each could be minimised.
- Estimate the uncertainty in the measured value of the wavelength.

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(b) Analysis of the light from the sodium lamp using a diffraction grating shows that there are photons of two different energies at wavelengths 589.0 nm and 589.6 nm.

(i) Calculate the energy difference ΔE between these two photons.

ΔE = ... J **[3]**

(ii) The light at these wavelengths can be seen as two separate lines when viewed through a diffraction grating. In order to be distinguishable from each other, the angular separation between the lines must be at least 0.02°.

Show that the lines will appear separated in the **second order** spectrum when the sodium lamp is viewed through a grating with 300 lines per millimetre.

[3]

5 **(a)*** Fig. 5 shows a thin slice of rock mounted on the face of a lead holder. The rock contains several different radioactive elements.

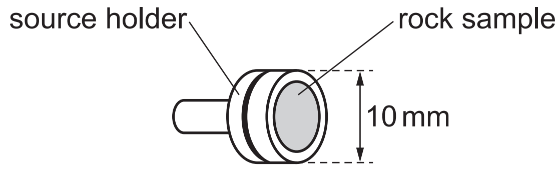

Fig. 5

Plan one or more experiments to determine the **nature** of the emissions from the sample.

A space has been left for you to draw one or more diagrams to show the arrangement of your apparatus

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(b) A grain of a radioactive powder which emits gamma rays accidentally falls onto the workbench.

A sensitive gamma-ray detector is used to look for this grain. The grain can be assumed to be a point source which emits radiation **uniformly in all** directions.

The background count-rate before the accident was negligible.

The detector registers a count-rate of $20\,s^{-1}$ when it is 1.0 m from the grain.

(i) Explain why the count-rate rises to $320\,s^{-1}$ when the detector is moved to 0.25 m from the grain.

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(ii) A thin lead sheet is now placed on the bench over the grain. This causes the count-rate to halve to $160\,s^{-1}$. The detector is moved from its position at 0.25 m towards the grain until the count-rate returns to $320\,s^{-1}$.

1 State the value of the count-rate if the sheet is now removed.

count-rate = ... s^{-1} **[1]**

2 Calculate the distance of the detector from the grain.

distance = ... m **[2]**

6 This question is about investigating the charging and discharging of capacitors.

Two students are given the circuit shown in Fig. 6.1. It consists of two resistors and two uncharged capacitors, a 10 V supply and a two-way switch **S**.

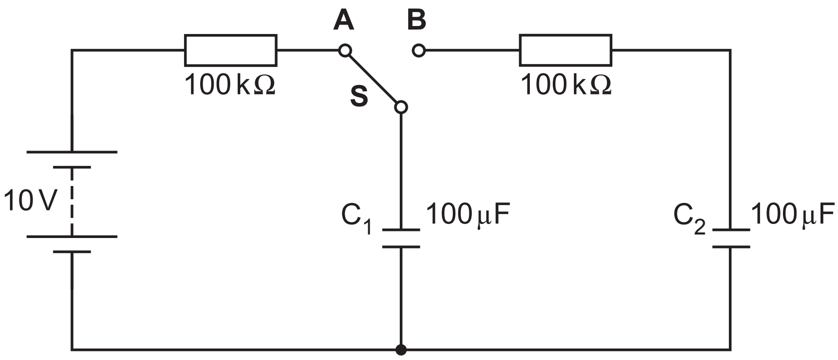

Fig. 6.1

(a) The first student is asked to investigate the charging of the capacitor C_1 when **S** is connected to **A**. She selects an ammeter of range 0 to 100 μA reading to 2 μA and a stopwatch reading to 0.1 s.

Discuss whether she has made a sensible choice of equipment for this experiment.

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(b) The second student is asked to investigate the change of potential difference (voltage) *V* with time *t* across each capacitor from the instant that **S** is moved from **A** to **B**.

(i) Explain why the final potential difference across each capacitor is 5.0 V.

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(ii) Predict the outcome of the experiment by sketching **two** graphs on Fig. 6.2 to display the results that the student should obtain for each capacitor. Label them C_1 and C_2.

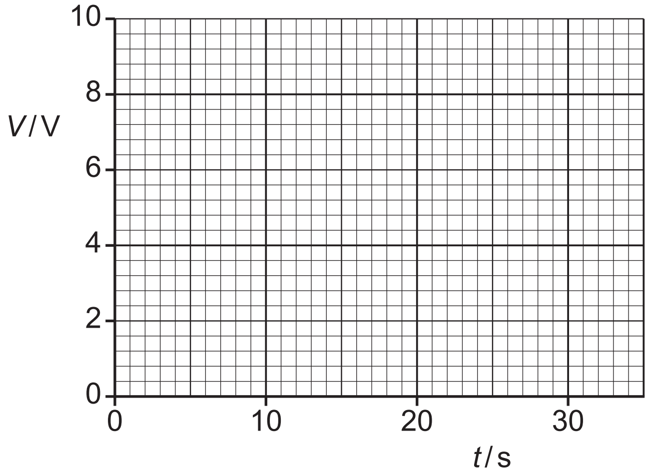

Fig. 6.2

[3]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).