Accredited

A Level Physics B (Advancing Physics)

H557/02 Scientific literacy in physics

Sample Question Paper

Date – Morning/Afternoon

Version 2.0

Time allowed: 2 hours 15 minutes

You must have:
- the Advance Notice (inserted)
- the Data, Formulae and Relationships Booklet

You may use:
- a scientific or graphical calculator

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.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided.
- Additional paper may be used if required but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.

INFORMATION
- The total mark for this paper is **100**.
- 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 **24** pages.

[601/4745/3] DC (…)

SECTION A

Answer **all** the questions.

1 A converging lens is used to form a real image of an object on a screen. The object consists of a black line marked on a sheet of thin white paper illuminated from behind with red light as shown in **Fig. 1.1**.

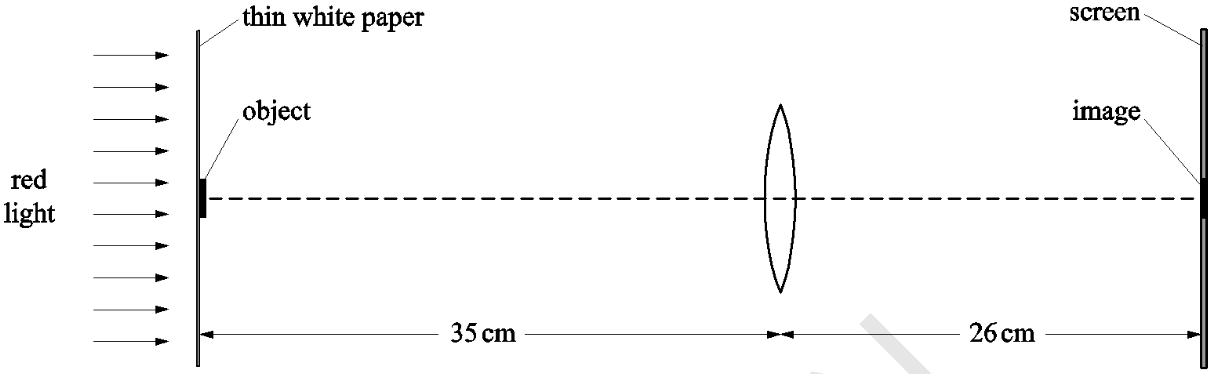

Fig. 1.1

(a) The object is 2.5 cm in height. Using data from the diagram:

(i) calculate the image height

height = ... cm **[2]**

(ii) calculate the power P of the lens.

P = ... D **[2]**

(iii) The ruler used to measure the object and image distances allows measurement to the nearest mm. However, the sharpest position of the image can be judged only to ± 5 mm.

Calculate the uncertainty ΔP in the power of the lens, explaining any assumptions made.

ΔP = ... D **[3]**

(b) When the red light is replaced with violet light, the position of the image moves 2.7 cm closer to the lens.

(i) Show that the power of the lens is about 7% greater for violet light than for red light.

[2]

(ii) Explain how this might affect a person wearing spectacles with lenses made from this glass.

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.... **[2]**

2 A sealed gas jar contains air as shown in **Fig.2.1**.

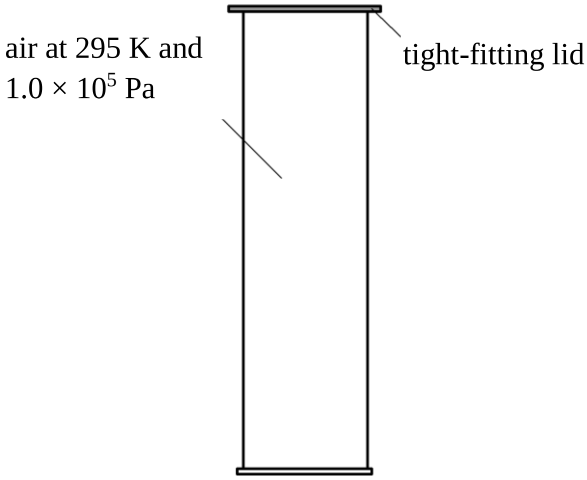

Fig.2.1

(a) The air is at a temperature of 295 K and is at a pressure of 1.0×10^5 Pa. The gas jar has an internal diameter of 50 mm and an internal height of 200 mm.

(i) Show that the gas jar contains about 10^{22} gas molecules.

$k = 1.38 \times 10^{-23}$ J K^{-1}

[3]

(ii) Assume that each molecule occupies, on average, a cubic space of volume x^3 as shown in **Fig. 2.2**. The distance x between the centre of adjacent cubes is the mean separation between molecules.

Show that the mean separation x between molecules is about 3 nm.

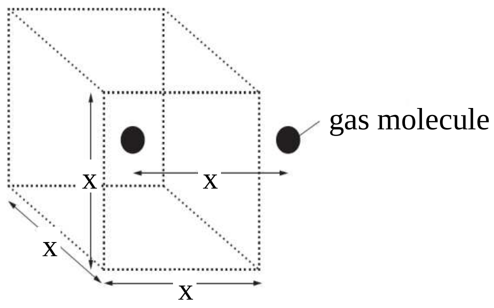

Fig. 2.2

[2]

(b) **(i)** Show that the r.m.s. speed of a molecule of an ideal gas is given by the equation

$$\text{r.m.s. speed} = \sqrt{\frac{3kT}{m}}$$

[2]

(ii) A crystal of iodine is placed at the bottom of the gas jar. The iodine vapourises. After 5 minutes iodine vapour is detected at a height of 12 cm above the crystal.

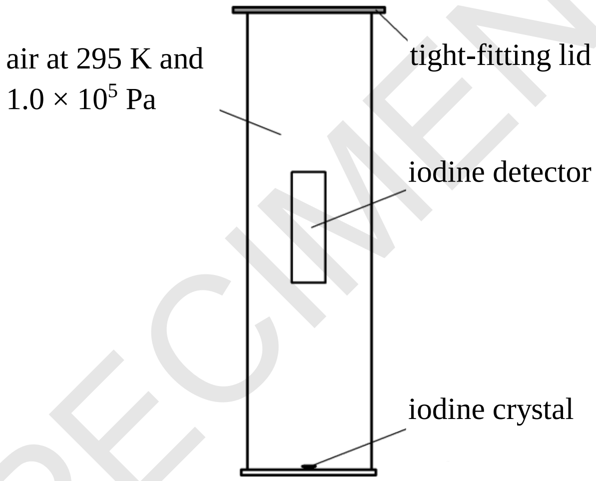

Fig. 2.3

Assuming that iodine vapour behaves as an ideal gas, calculate the mean distance travelled by an iodine molecule in 5 minutes and explain why the iodine vapour travelled only about 12 cm in that time.

$k = 1.4 \times 10^{-23}$ J K^{-1}
mass of iodine molecule, $m = 2.1 \times 10^{-25}$ kg

[3]

3 In the Geiger–Marsden scattering experiment, alpha particles from a radium source were directed on thin gold foil as in **Fig. 3.1**. The number of alpha particles scattered at different angles from the gold foil was measured per unit time.

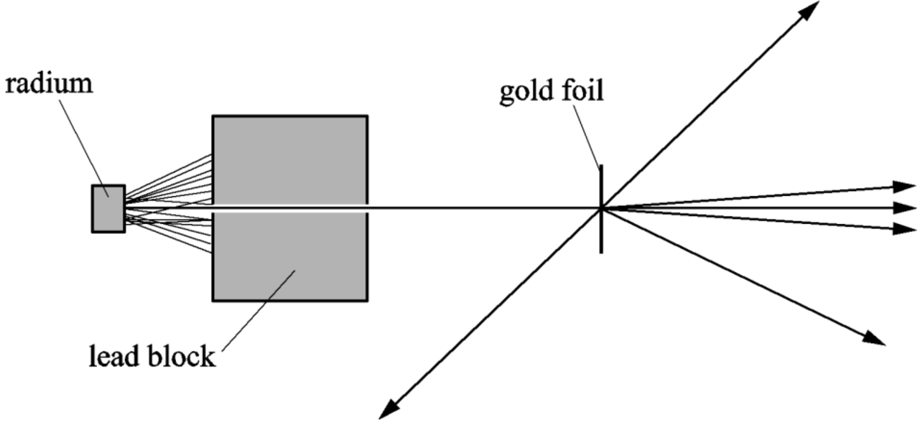

Fig. 3.1

(a) The apparatus was set up inside a vessel from which all air had been removed. The beam of alpha particles passed through a narrow hole drilled in a lead block positioned between the radium source and the gold foil.

Explain why these arrangements were necessary.

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…………………………………………………………………………………………...... **[2]**

(b) Two of the paths taken by alpha particles near a gold nucleus are shown in **Fig. 3.2**.

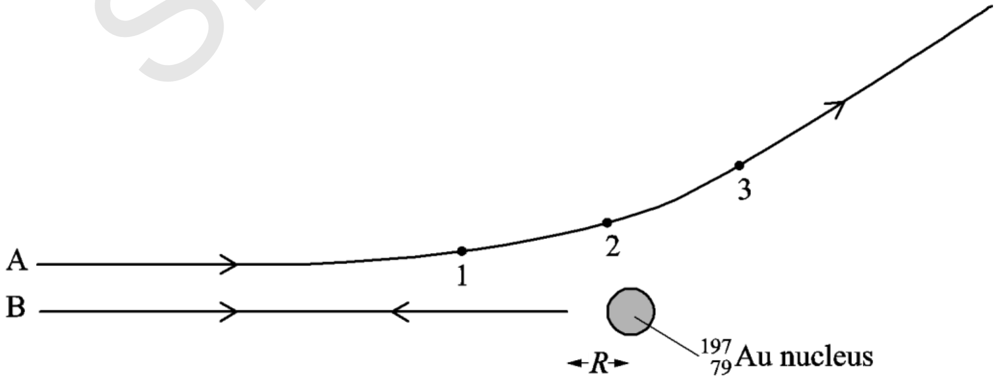

Fig. 3.2

(i) Three points on path **A** are labelled **1**, **2** and **3**. Point **2** is the closest distance of approach to the gold nucleus, while points **1** and **3** are each twice as far from the centre of the nucleus as point **2**.

Draw arrows on **Fig. 3.2** to show the direction and magnitude of the force acting on the alpha particle at points **1**, **2** and **3**.

[3]

(ii) Alpha particles following path **B** are deflected through 180°.

Calculate the minimum distance R from the centre of the nucleus for these alpha particles.

kinetic energy of alpha particles = 4.8 MeV

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

minimum distance R = **………………….** m **[4]**

SECTION B

Answer **all** the questions.

4 **(a)** A student uses the simple electrical circuit shown in **Fig. 4.1** to find the conductivity of a metal alloy.

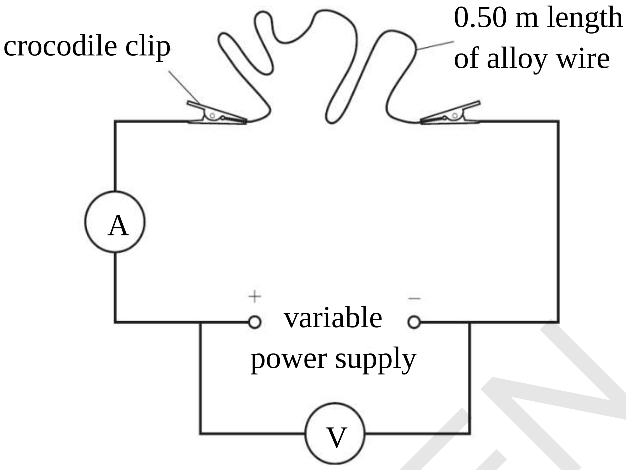

Fig. 4.1

The student uses an alloy wire of length 0.50 m and diameter of 0.213 mm. The student obtains the preliminary readings: I = 0.18 A, V = 1.4 V.

(i) Calculate the electrical conductivity of the alloy given by the student's readings.

conductivity of alloy = ……………………… S m^{-1} **[3]**

(ii) The accepted value for electrical conductivity of the alloy is significantly larger than the value obtained from the student's data.

Assuming the uncertainties in the student's readings are negligible, suggest and explain a reason for the difference.

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(b) An electromagnetic lock consists of a core and coil attached to a door-frame, and a steel plate attached to the door. In **Fig. 4.2** the steel plate is very close to, but not touching, the electromagnet core.

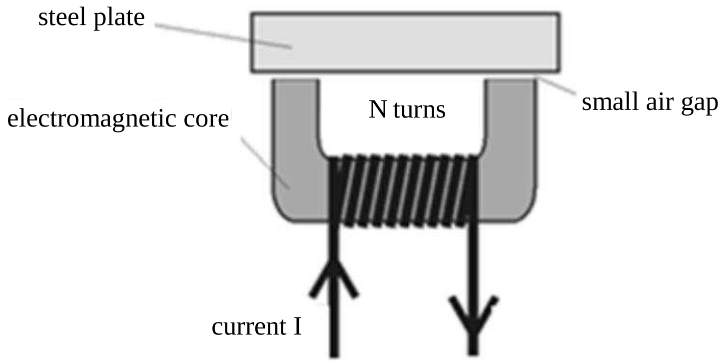

Fig. 4.2

(i) Draw three lines of magnetic flux on **Fig. 4.2** and explain why there is a strong attractive force between the electromagnetic core and steel plate.

[2]

(ii) Use ideas of permeance to explain why the attractive force becomes much stronger when the core and plate are in contact.

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.... **[3]**

(c) The experimental diagram of **Fig. 4.1** and the door-lock of **Fig. 4.2**, repeated in **Fig. 4.3**, are both types of series circuit.

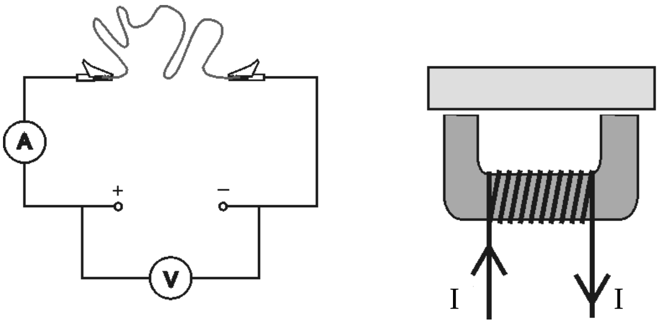

Fig. 4.3

There are analogies between electrical and magnetic circuits.

Complete the table to compare the electrical and magnetic features of the circuits shown in **Fig. 4.3**.

electrical circuit feature	**corresponding magnetic circuit feature**
power supply	
e.m.f.	
current in the circuit	
conductance	
the conductance of the connecting leads is greater than that of the alloy metal wire	

[5]

5 This question is about the vertical forces and motion of an object floating in water. **Fig. 5.1** shows a cylindrical rod of length L and cross-sectional area A floating vertically in water. The rod is weighted at the one end to ensure it floats vertically.

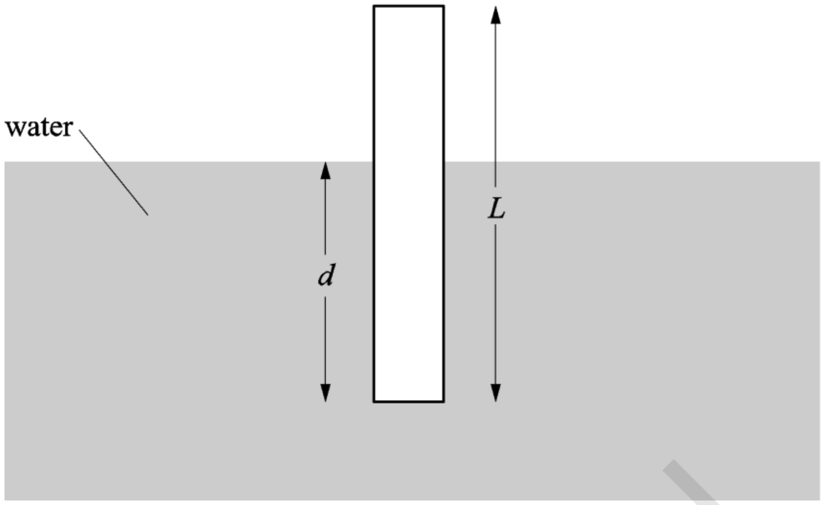

Fig. 5.1

(a) Any object immersed in a fluid experiences an upwards force (upthrust) which is equal to the weight of the displaced fluid; in **Fig. 5.1** this is the weight of water of volume Ad.

In equilibrium, the situation shown in **Fig. 5.1**, the distance between the water level and the base of the cylinder is d.

(i) Show that the depth d is given by

$$d = \frac{m}{A\rho_W}$$

where m is the mass of the cylindrical rod and ρ_w is the density of water.

[2]

(ii) Explain in terms of forces why a rod of mean density ρ_{rod} **cannot** float in water of density ρ_w if $\rho_{rod} > \rho_w$.

[2]

(b) The rod is now pushed vertically down into the water by a distance s, where s is of the order of one or two cm.

Show that the resultant acceleration a is given by

$$a = -\left(\frac{\rho_w g A}{m}\right)s$$

and explain why it would oscillate with simple harmonic motion of period T where

$$T = 2\pi\sqrt{\frac{m}{\rho_W g A}}$$

[5]

(c)* Measuring the period of oscillation of a floating rod is one way of determining the acceleration of gravity but it is not as popular as using a simple pendulum.

Suggest and explain reasons why the pendulum method is likely to be chosen if a value of g with a small uncertainty is wanted.

In your answer you may wish to consider a pendulum of length 1m and a rod of mass 1 kg and cross sectional area 0.005 m^2 floating in water of density 1000 kg m^{-3}. **[6]**

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6 This question is about analysing the motion of sub-atomic particles.

(a) **Fig. 6.1** shows a collision of an alpha particle (α) with a stationary helium nucleus (He). The paths of the alpha particle and the helium nucleus can be observed in a cloud chamber. The velocities of the particles add as shown in **Fig. 6.2**.

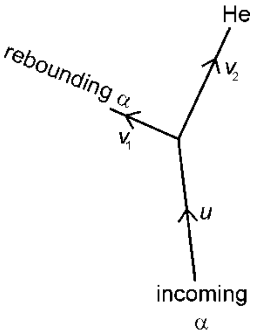

Fig. 6.1

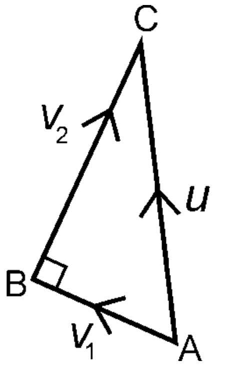

Fig. 6.2

(i) **Fig. 6.2** shows that

velocity u of α before collision = velocity v_1 of α after collision + velocity v_2 of He

Use the principle of conservation of momentum to explain why the velocities can only add in this way if the mass of an alpha particle, m_α, is the same as the mass of a helium nucleus, m_{He}.

[2]

(ii) **Fig. 6.2** also shows that the vector addition triangle **ABC** is a right-angled triangle. Explain how this shows that the collision is elastic (there is no loss of kinetic energy).

[2]

(b) **Fig. 6.3** shows a positron–electron pair being produced by a gamma photon in a cloud chamber. There is a uniform magnetic field acting perpendicularly into the diagram, shown by the shaded area.

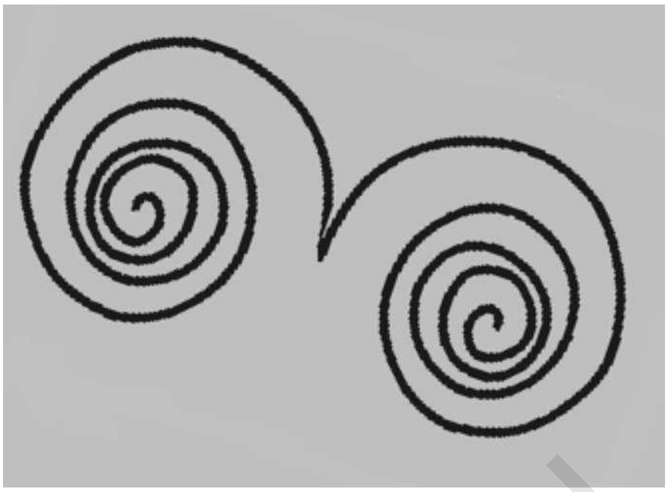

Fig. 6.3

Add a line to **Fig. 6.3** to show the path of the incoming gamma photon. Explain why the gamma photon left **no** track in the cloud chamber, and why the positron and electron follow the paths shown in **Fig. 6.3**.

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…………………………………………………………………………………………...... **[6]**

(c) **Fig. 6.4** shows an annihilation in a cloud chamber. There is a uniform magnetic field acting perpendicularly into the diagram, shown by the shaded area. An antiproton (p^-) enters near the bottom and collides with a stationary proton. The annihilation creates eight hadrons numbered 1 – 8 in **Fig. 6.4.**

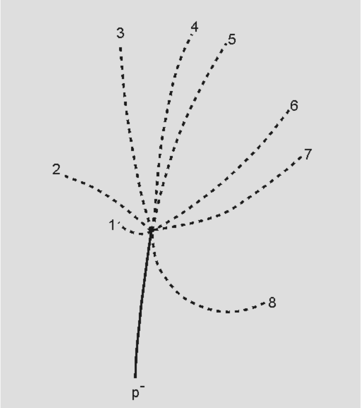

Fig. 6.4

(i) Explain how the tracks of the particles in **Fig. 6.4** show that charge is conserved in this reaction.

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.... **[2]**

(ii) Hadron 8 in **Fig. 6.4** moves on a track with initial radius of 4.6 mm.

Calculate the velocity of this hadron.

hadron charge = 1.6×10^{-19} C
hadron mass = 2.5×10^{-28} kg
magnetic field strength = 2.2 T

velocity = ...m s^{-1} **[3]**

SECTION C

Answer **all** the questions**.**

This section is based on the Advance Notice article, which is an insert.

7* SOHO is mostly constructed from aluminium, although low-density composite materials using carbon fibres are now often used for satellite construction. With reference to the particular physical properties of aluminium, discuss its suitability as a material for this craft mentioning both advantages and disadvantages of aluminium during the launch and space environment. **[6]**

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8 This question is about the solar corona and the particles emitted from it.

(a) The article describes the temperature of the solar corona as being far above that of the photosphere (line 13). The coronal X-rays detected by SOHO are in the wavelength range 0.10 nm to 10 nm.

Use these data to show how the temperature of the solar corona compares with that of the visible surface of the Sun (about 6000 K).

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

[3]

(b) Measurements by SOHO's LASCO instrument showed that coronal mass ejections (CMEs) travel at speed between 20 km s^{-1} and 3200 km s^{-1}, with an average of 490 km s^{-1}. Suggest and explain how authorities can use these data, together with continuing observations from SOHO, to reduce the effects that a large CME could have upon the Earth.

[3]

9 This question is about the orbit of SOHO.

(a) Show that the centripetal acceleration experienced by SOHO as it orbits the Sun at position L1 (lines 7 to 10 and Fig. 2 in the article) is about 6 x 10^{-3} m s^{-2}.

1 year = 3.2×10^{7} s

[4]

(b) By calculating the gravitational forces exerted on SOHO by the Earth and the Sun, explain how SOHO is kept at point L1.

mass of Sun = 2.0×10^{30} kg
mass of Earth = 6.0×10^{24} kg
mass of SOHO = 1900 kg

[5]

10 A comet's distance from the Sun varies considerably as it moves through the Solar System (line 32 of the article). Data for Comet Halley are shown in **Fig. 8.1**.

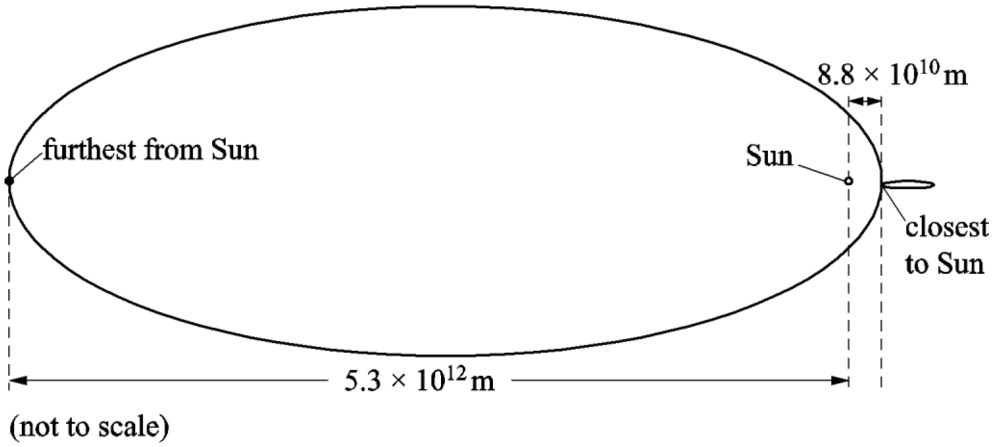

Fig. 8.1

At its furthest distance from the Sun, Comet Halley has a speed of 880 m s^{-1}. Show that it is travelling about 60 times faster than this at its closest approach.

mass of Sun = 2.0×10^{30} kg
mass of Comet Halley = 2.2×10^{14} kg

[4]

END OF QUESTION PAPER

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A Level Physics B (Advancing Physics)

H557/02 Scientific literacy in physics

Sample Advance Notice Article

To be read on receipt

To prepare candidates for the examination taken on Date/Year

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NOTES FOR GUIDANCE (CANDIDATES)

1. This leaflet contains an article which is needed in preparation for a question in the externally assessed examination H557/02 Scientific literacy in physics.
2. You will need to read the article carefully and also have covered the learning outcomes for A Level in Physics B (Advancing Physics). The examination paper will contain questions on the article. You will be expected to apply your knowledge and understanding of the work covered in A Level in Physics B (Advancing Physics) to answer this question. There are 20–25 marks available on the question paper for this question.
3. You can seek advice from your teacher about the content of the article and you can discuss it with others in your class. You may also investigate the topic yourself using any resources available to you.
4. You will not be able to bring your copy of the article, or other materials, into the examination. The examination paper will contain a fresh copy of the article as an insert.
5. You will not have time to read this article for the first time in the examination if you are to complete the examination paper within the specified time. However, you should refer to the article when answering the questions.

This document consists of **4** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER/INVIGILATOR

- Do not send this Insert for marking; it should be retained in the centre or recycled. Please contact OCR Copyright should you wish to re-use this document.

Observing the Sun and comets from SOHO

The Solar and Heliographic Observatory (SOHO, shown in **Fig. 1**) is a spacecraft resulting from a highly successful collaboration between NASA and the European Space Agency (ESA). It was launched in December 1995 and it was originally intended that it should be in operation for only two years. It proved to be such a successful mission that its lifetime has been extended several times. It is a relatively small craft with a mass of 1900 kg but it is packed with instruments studying a wide range of the Sun’s properties and emissions.

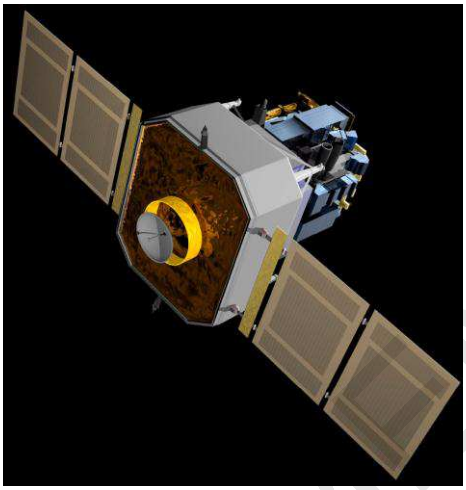

Fig. 1: artist’s picture of the SOHO spacecraft

SOHO always faces the Sun enabling data to be collected continuously. It is in a fixed orbit about the Sun located at what is called the First Lagrangian Point (L1 in **Fig. 2**) and under the joint action of the Sun and the Earth always remains approximately on a straight line between the Earth and the Sun, about 1.5 million km from the Earth.

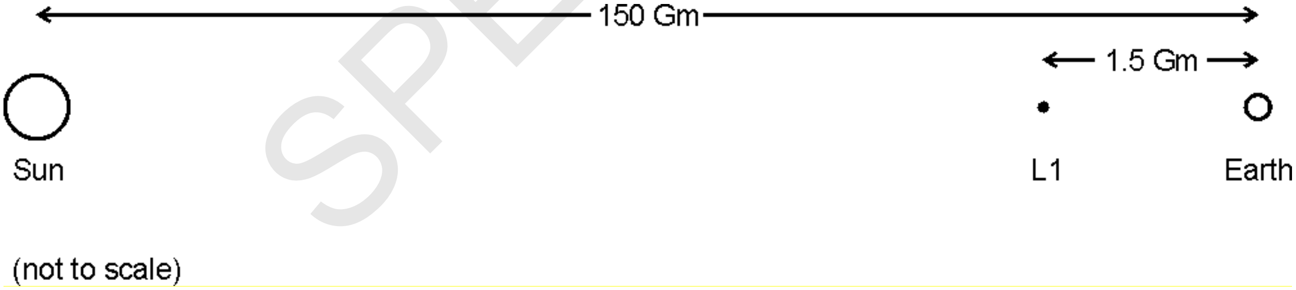

Fig. 2: diagram showing the Lagrange point L1 at which SOHO is located

SOHO was designed to tackle three fundamental questions about the Sun:

1. what is the structure and dynamics of the inside of the Sun?
2. what produces the solar corona and raises its temperature far above the 5800 K of the photosphere (the bright surface of the Sun)
3. where does the solar wind come from, and what accelerates it?

The Sun’s corona has long fascinated astronomers. It has been known for many years that the Sun is a strong emitter of "soft" X-rays; these can only have been emitted from the low-density corona because the denser layers of the Sun absorb any X-rays originating from within the Sun.

From the Earth the corona is visible only during an eclipse, as in **Fig. 3**, so one of SOHO's instruments, the large angle and spectrometric coronagraph (LASCO), was designed to create a permanent artificial eclipse by blocking out the Sun's disc. This allowed the corona to be studied continuously.

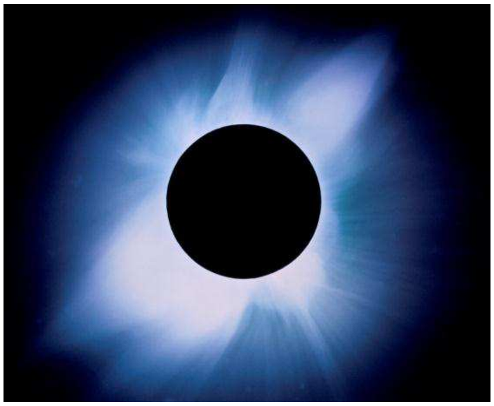

Fig. 3: the Sun's corona during a total eclipse

Other instruments on SOHO detect the particles emitted by the Sun in the solar wind. These particles, mostly electrons and protons, flow continually outwards from the Sun, but are often interrupted by large bursts of plasma called coronal mass ejections (CMEs) travelling at speeds up to 3000 km s^{-1}. Any of these sudden outpourings of energetic charged particles which head towards the Earth can have serious negative effects on electronic circuits, disabling satellites and causing huge fluctuations in the Earth's magnetic field. An event of this type in 1989 caused a massive blackout in Quebec as induced currents in the supply lines made circuit breakers trip.

In December 2013, the world was captivated by the progress of a comet as it headed towards the Sun. **Fig.4**, composed of a series of coronagraphs from the LASCO instrument, is a time-lapse record of Comet Ison near the Sun.

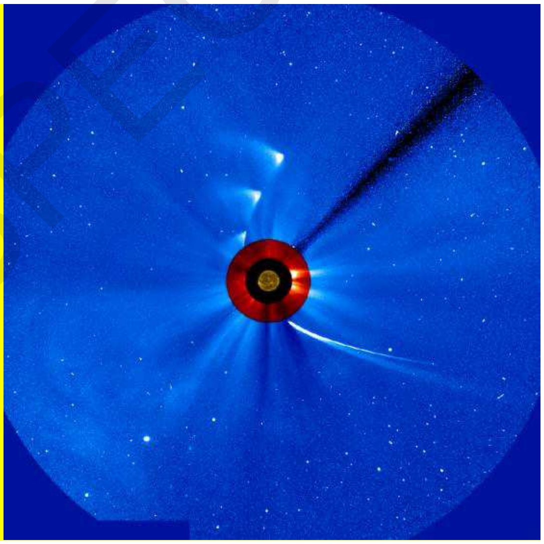

Fig. 4: a composite photograph of Comet Ison's close encounter with the Sun, made up from images captured by the SOHO spacecraft.

Many comets have elliptical orbits of such high eccentricity that they pass very close to the Sun. For this reason, from its stable position perpetually facing the Sun, SOHO has become history's most prolific observer and discoverer of comets. Although Comet Ison did not crash into the Sun as many had predicted, the close gravitational encounter of Comet Ison with the Sun caused it to break up and it was destroyed in the dramatic endings captured in Fig. 4.

END OF ADVANCE NOTICE ARTICLE

Copyright Information:

Fig. 1: Artist picture of SOHO spacecraft permission granted by Alex Lutkus/NASA/Science Photo Library © sciencephoto.com, image ref. C008/4025

Fig 3: Photograph of the Sun’s corona during a total eclipse. © Rev. Ronald Royer/Science Photo Library, image ref: R506/0144

Fig. 4: Photograph of Comet courtesy of Courtesy of SOHO consortium. SOHO is a project of international cooperation between ESA and NASA. © http://www.thesuntoday.org/tag/soho/#gallery/6483c98a9fcbf6f800e4d2ba8be0328d/295/0