

A Level Physics B (Advancing Physics)
H557/02 Scientific literacy in physics
Sample Question Paper

Date – Morning/Afternoon

Time allowed: 2 hours 15 minutes



You must have:

- the Advance Notice (inserted)
- the Data, Formulae and Relationships Booklet

You may use:

- a scientific calculator



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|----------------------|--|--|--|--|--|--|-------------------------|--|--|--|--|
| 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.
- 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.

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.

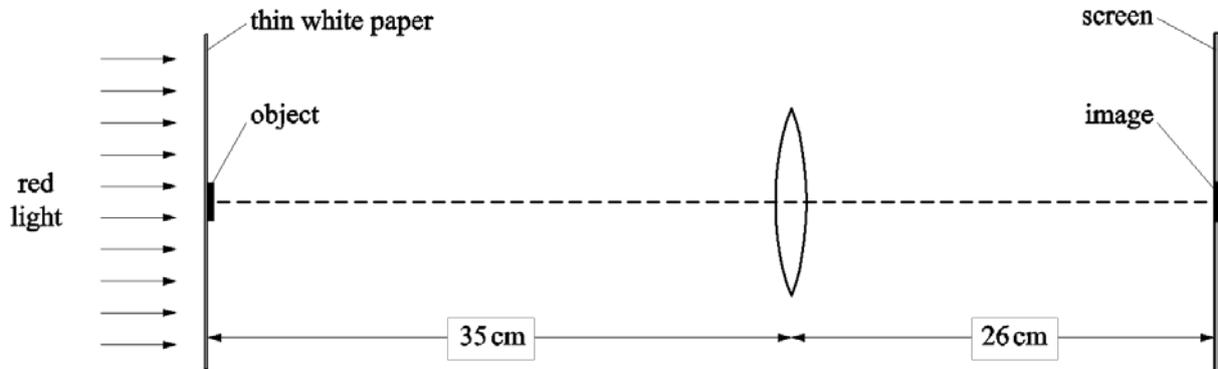


Fig. 1.1

- (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.

$$\Delta P = . \dots\dots\dots D \quad [3]$$

- (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**.

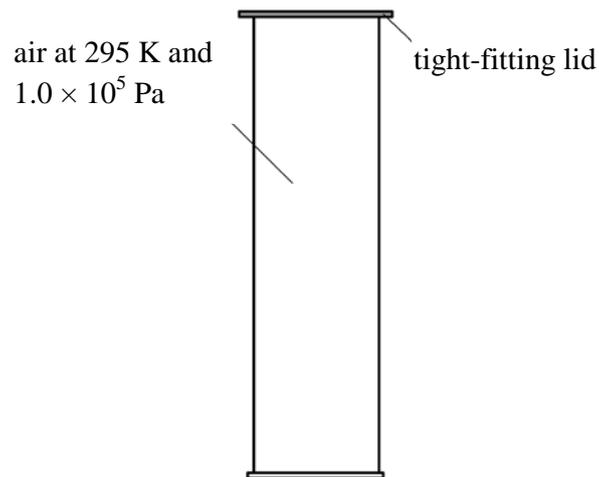


Fig.2.1

- (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.

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

[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.

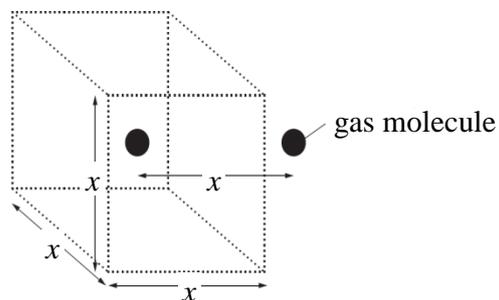


Fig. 2.2

[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.

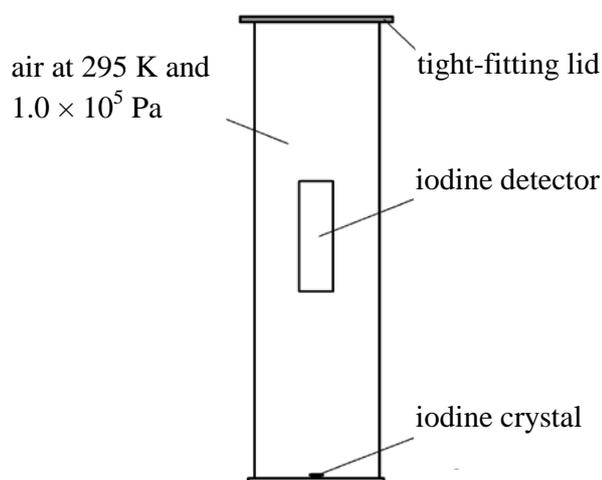


Fig. 2.3

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.

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

$$\text{mass of iodine molecule, } m = 2.1 \times 10^{-25} \text{ kg}$$

[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.

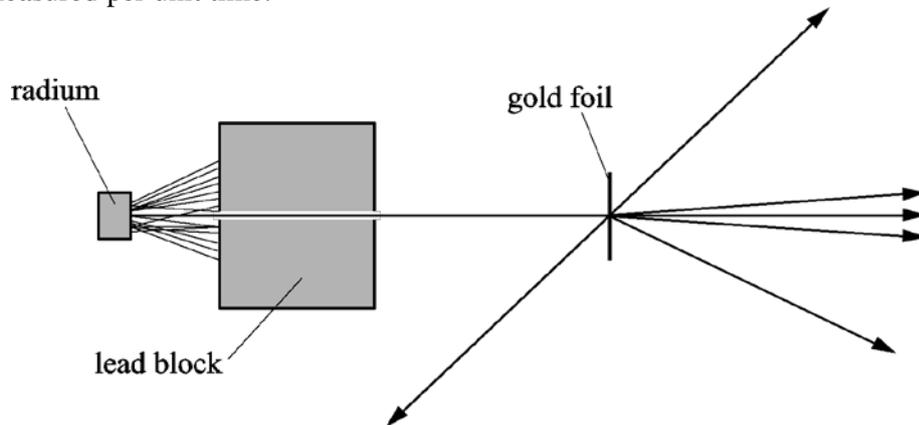


Fig. 3.1

- (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**.

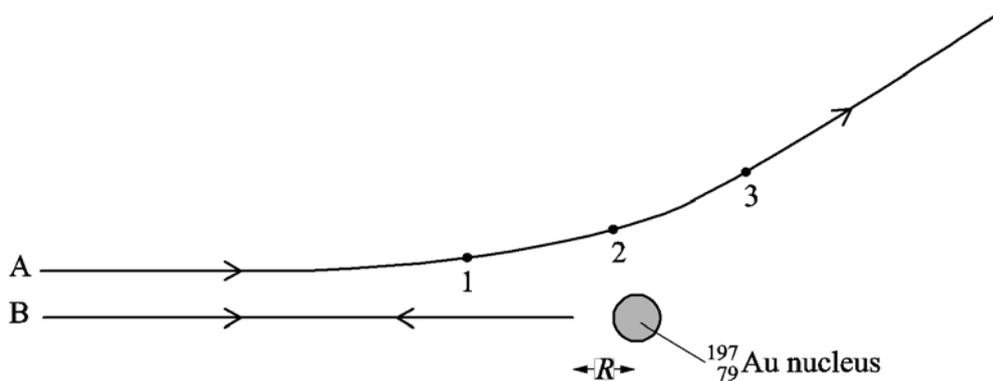


Fig. 3.2

- (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

$$k = \frac{1}{4\pi\epsilon_0} = 9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

minimum distance $R = \dots\dots\dots$ 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.

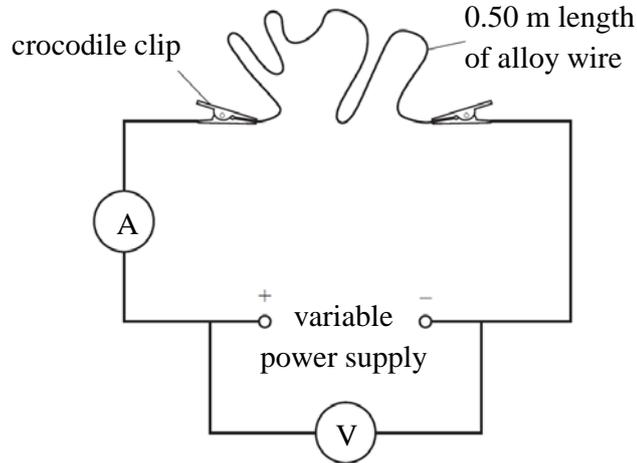


Fig. 4.1

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

- (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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[2]

- (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 electromagnetic core.

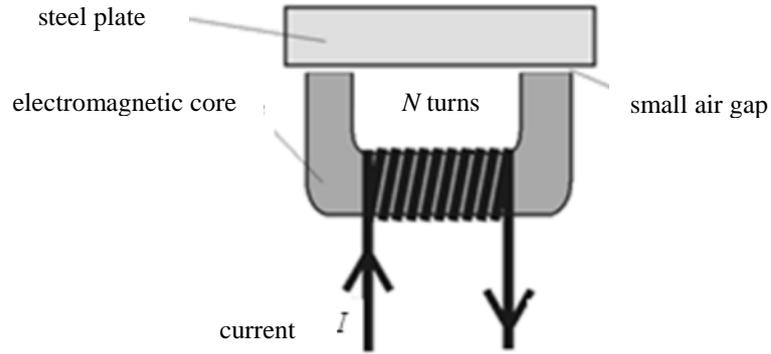


Fig. 4.2

- (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.

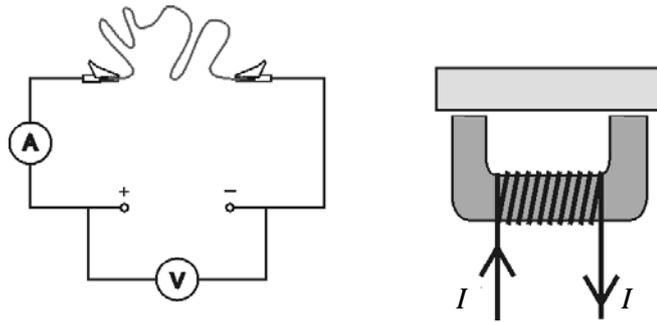


Fig. 4.3

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.

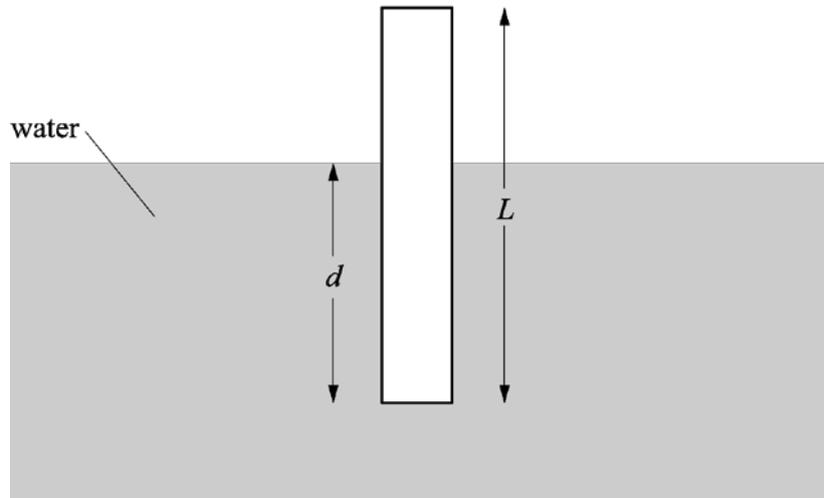


Fig. 5.1

- (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 $\rho_{\text{rod}} > \rho_w$.

[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} .

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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**.

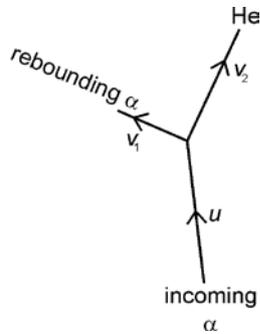


Fig. 6.1

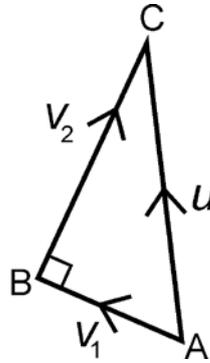


Fig. 6.2

- (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) 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 $6 \times 10^{-3} \text{ m s}^{-2}$.

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

[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.

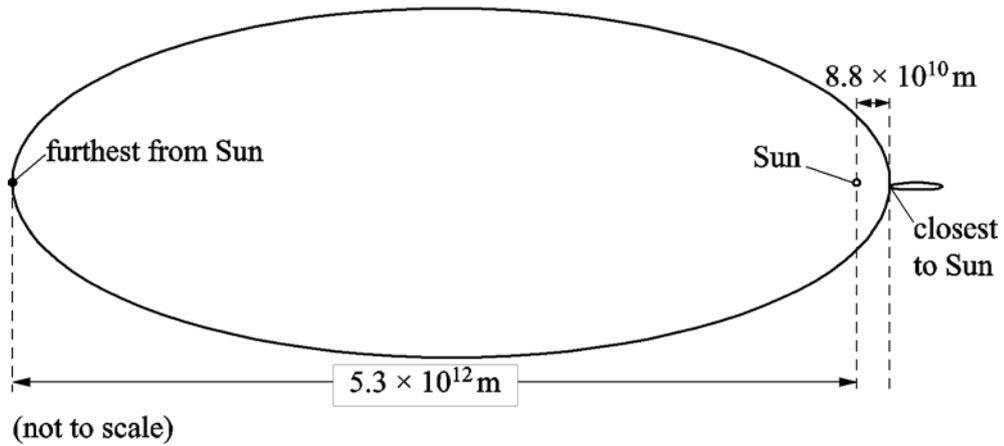


Fig. 8.1

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.

$$\text{mass of Sun} = 2.0 \times 10^{30} \text{ kg}$$

$$\text{mass of Comet Halley} = 2.2 \times 10^{14} \text{ kg}$$

[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



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

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Observing the Sun and comets from SOHO

The Solar and Heliospheric 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.

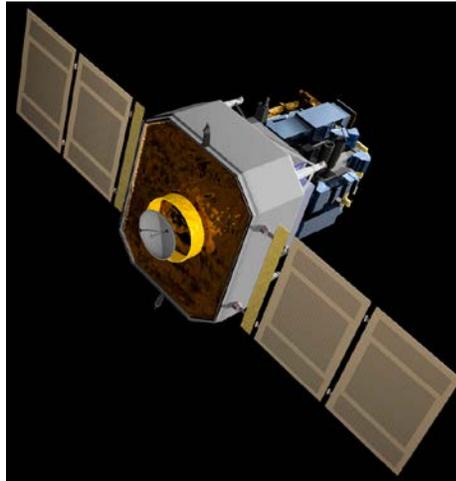
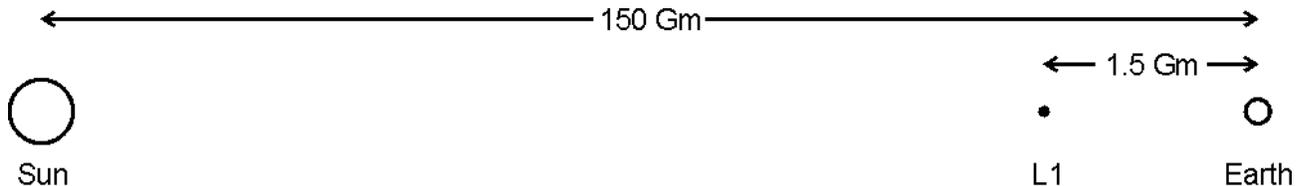


Fig. 1: artist's picture of the SOHO spacecraft

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.



(not to scale)

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.

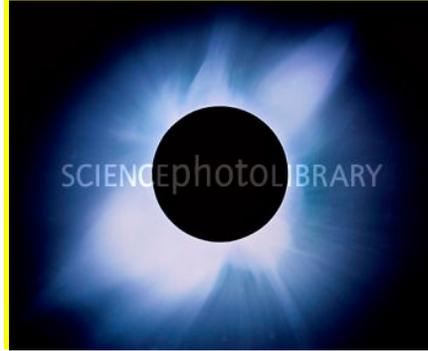


Fig. 3: the Sun's corona during a total eclipse <science photo library R506/0144>

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.

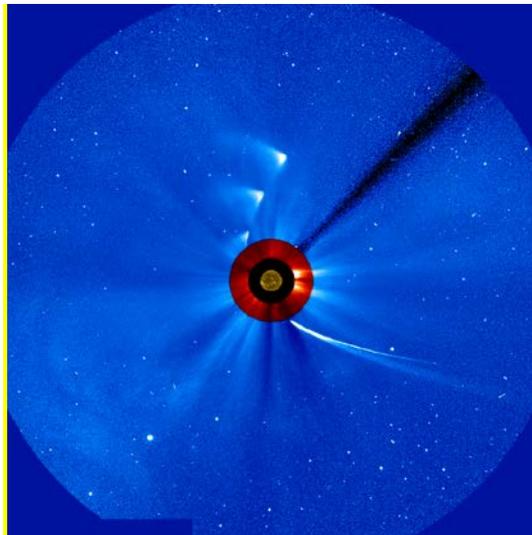


Fig. 4: a composite photograph of Comet Ison's close encounter with the Sun, made up from images captured by the SOHO spacecraft.

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

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

Fig. 2: 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>

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...day June 20XX – Morning/Afternoon

MAXIMUM MARK 100

MARKING INSTRUCTIONS**PREPARATION FOR MARKING****SCORIS**

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *scoris assessor Online Training*; *OCR Essential Guide to Marking*.
2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal <http://www.rm.com/support/ca>
3. Log-in to scoris and mark the **required number** of practice responses (“scripts”) and the **required number** of standardisation responses.

YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

MARKING

1. Mark strictly to the mark scheme.
2. Marks awarded must relate directly to the marking criteria.
3. The schedule of dates is very important. It is essential that you meet the scoris 50% and 100% (traditional 50% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.
4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the scoris messaging system.

5. Work crossed out:
- a. where a candidate crosses out an answer and provides an alternative response, the crossed out response is not marked and gains no marks
 - b. if a candidate crosses out an answer to a whole question and makes no second attempt, and if the inclusion of the answer does not cause a rubric infringement, the assessor should attempt to mark the crossed out answer and award marks appropriately.
6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there then add a tick to confirm that the work has been seen.
7. There is a NR (No Response) option. Award NR (No Response)
- if there is nothing written at all in the answer space
 - OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
 - OR if there is a mark (e.g. a dash, a question mark) which isn't an attempt at the question.

Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).

8. The scoris **comments box** is used by your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**
- If you have any questions or comments for your Team Leader, use the phone, the scoris messaging system, or e-mail.
9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:

- Read through the whole answer from start to finish.
- Decide the level that **best fits** the answer – match the quality of the answer to the closest level descriptor.
- To select a mark within the level, consider the following:

Higher mark: A good match to main point, including communication statement (in italics), award the higher mark in the level

Lower mark: Some aspects of level matches but key omissions in main point or communication statement (in italics), award lower mark in the level.

Level of response questions on this paper are **5(c) and 7(a)**.

11. Annotations

| Annotation | Meaning |
|---------------------|--|
| DO NOT ALLOW | Answers which are not worthy of credit |
| IGNORE | Statements which are irrelevant |
| ALLOW | Answers that can be accepted |
| () | Words which are not essential to gain credit |
| — | Underlined words must be present in answer to score a mark |
| ECF | Error carried forward |
| AW | Alternative wording |
| ORA | Or reverse argument |

12. Subject-specific Marking Instructions

INTRODUCTION

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

| Question | | Answer | Marks | Guidance |
|----------|-----|---|--------------|--|
| 1 | (a) | (i) $h_{\text{image}} = (v/u) \times h_{\text{object}}$ or $= (26 / 35) \times 2.5$ ✓ $= 1.9$ (cm) ✓ | 2 | 1.9 (cm) gains both marks |
| | | (ii) $(P = 1/f = 1/v - 1/u) = 1/(0.35) - 1/(-0.26)$ ✓ $(= 2.86 + 3.85) = 6.7$ (D) ✓ | 2 | method mark for adopting the correct method and evaluation mark for getting the correct answer. 6.7 (D) gets both marks |
| | | (iii) Justifies ignoring Δu as Δv is much greater ✓ uses $v = 26.5$ or 25.5 ✓ evaluation $\Delta P = 0.08$ (D) from 25.5 or 0.07 (D) from 26.5 ✓ | 3 | allow $\Delta P/P = \Delta v/v$ giving $\Delta P = 0.1$ (D) <i>alternative method</i> This method makes no simplifying assumption Attempt to find P_{max} or P_{min} using $\Delta u = 0.1$ & $\Delta v = 0.5$ ✓ in same direction, both to increase P or both to decrease P (e.g. 35.1 cm & 26.5 cm or 34.9 cm & 25.5 cm) ✓ evaluation $\Delta P = 0.09$ (D) ✓ |
| | (b) | (i) New $P = 1/0.35 - 1/(-0.26 - 0.027) = 7.2$ D ✓ Percentage increase = $[(7.2 \text{ D} - 6.7 \text{ D})/6.7 \text{ D}] \times 100\%$ $= 7.5\%$ ($\approx 7\%$) ✓ | 2 | Allow use of unrounded figures for both P s, gives 6.6% 7.46 or 7.5 gains both marks |
| | | (ii) different colours will be imaged at different places ✓ so objects emitting/reflecting light of several colours will not be seen sharply/will be fuzzy/ will have coloured edges ✓ | 2 | |
| | | | Total | 11 |

| Question | | | Answer | Marks | Guidance |
|--------------|-----|------|---|-----------|--|
| 2 | (a) | (i) | $V = 0.20 \times \pi \times 0.025^2 = 3.9 \times 10^{-4} \text{ (m}^3\text{)} \checkmark$ $N = pV/kT \text{ or } N = (1.0 \times 10^5 \times 3.9 \times 10^{-4}) / (295 \times 1.38 \times 10^{-23}) \checkmark$ $= 9.7 \times 10^{21} (\approx 10^{22}) \checkmark$ | 3 | 1 st mark for getting the volume of the jar; marks 2 and 3 are method and evaluation marks for calculation of the number of molecules. Correct answer gains 3 marks |
| | | (ii) | $V \text{ per molecule} = 3.9 \times 10^{-4} / 9.5 \times 10^{21} = 4.1 \times 10^{-26} \text{ (m}^3\text{)} \checkmark$ $x = \sqrt[3]{(4.1 \times 10^{-26})} = 3.4 \times 10^{-9} \text{ (m)} (\approx 3 \text{ nm}) \checkmark$ | 2 | Can use 10^{22} to get $3.9 \times 10^{-26} \text{ m}^3$ (gives the same x) Correct answer gains 2 marks |
| | (b) | (i) | $pV = \frac{1}{3} N m \overline{c^2} = NkT \checkmark$ $\overline{c^2} = 3kT/m \Rightarrow \text{r.m.s. speed} = \sqrt{\overline{c^2}} \checkmark$ | 2 | |
| | | (ii) | $\text{r.m.s. speed} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 295}{2.1 \times 10^{-25}}} = 240 \text{ (m s}^{-1}\text{)} \checkmark$ distance travelled in the 5 minutes = $240 \times 300 = 72\,000 \text{ m} \checkmark$ random walk due to multiple collisions (with air molecules) \checkmark | 3 | |
| Total | | | | 10 | |

| Question | | Answer | Marks | Guidance |
|--------------|-----|--|----------|--|
| 3 | (a) | Narrow hole to collimate or ensure all alpha particles following same track to start with or create a parallel beam ✓ air removed because it would absorb alpha particles before they reached detector ✓ | 2 | |
| | (b) | (i) All arrows radially outward from the nucleus ✓ arrows 1 and 3 of equal length and shorter than arrow 2 ✓ arrow 2 is 4 × longer than the others ✓ | 3 | |
| | | (ii) At closest approach, PE = initial alpha KE ✓ $PE (= VQ_{He}) = kQ_{Au}Q_{He}/R$ ✓ $9.0 \times 10^9 \times (79e) \times (2e)/R = 4.8 \times 10^6 \times e$ ✓ $(R = 9.0 \times 10^9 \times 158e^2 / (4.8 \times 10^6 \times e))$ $= 9.0 \times 10^9 \times 158 \times (1.6 \times 10^{-19}) / (4.8 \times 10^6)$ $= 4.7 \times 10^{-14} \text{ (m)}$ ✓ | 4 | 1 st mark is for applying conservation of energy 2 nd mark is for choice of the appropriate equations 3 rd mark is for correct substitution into energy equation 4 th mark is for correct evaluation. Correct answer gains 4 marks |
| Total | | | 9 | |

| Question | | | Answer | Marks | Guidance |
|--------------|-----|------|--|-----------|---|
| 4 | (a) | (i) | $G = I/V = 0.18 / 1.4 = 0.129 \text{ (S)} \checkmark$ $G = \sigma A/L \Rightarrow \sigma = GL/A = 0.129 \times 0.5 / (\pi \times [1/2 \times 0.213 \times 10^{-3}]^2) \checkmark$ $= 1.8 \times 10^6 \text{ (S m}^{-1}\text{)} \checkmark$ <i>alternative method</i> $R = V/I = 0.18 / 1.4 = 7.8 \text{ (}\Omega\text{)} \checkmark$ $R = \rho L/A \Rightarrow \rho = RA/L = 7.8 \times (\pi \times [1/2 \times 0.213 \times 10^{-3}]^2) / 0.5 = 5.54 \times 10^{-6} \text{ (}\Omega \text{ m)} \checkmark$ $\sigma = 1/\rho = 1/(5.54 \times 10^{-6}) = 1.8 \times 10^6 \text{ (S m}^{-1}\text{)} \checkmark$ | 3 | <p>If done through resistance, the method mark for finding σ must include inversion of ρ.</p> <p>correct answer gains 3 marks</p> |
| | | (ii) | <p>(σ too low means that is G also too low so) either I should be larger or V should be smaller \checkmark</p> <p>there are p.d. losses across ammeter or croc clips/places where clips grip wire \checkmark</p> <p><i>alternative</i></p> <p>Resistance R increases or G decreases \checkmark</p> <p>current heats wire due to increased atomic vibrations hindering electron transport \checkmark</p> | 2 | 1 st mark is for the suggestion and the 2 nd for the explanation |
| | (b) | (i) | <p>Three complete continuous loops through core, air gap and plate (not crossing) \checkmark</p> <p>Flux lines tend to contract or straighten \checkmark</p> | 2 | |
| | | (ii) | <p>Air has a much lower permeability than steel or the core \checkmark</p> <p>Overall permeance of the magnetic circuit is much lower when air is present \checkmark</p> <p>Giving smaller flux and so less force with air gap \checkmark</p> | 3 | allow suitable alternative terms |
| | (c) | | <p>Power supply ~ current carrying coil \checkmark</p> <p>emf ~ NI \checkmark</p> <p>I ~ flux or ϕ \checkmark</p> <p>conductance ~ permeance \checkmark</p> <p>value for circuit leads/electromagnet core is greater than that for the alloy wire /steel plate \checkmark</p> | 5 | award 1 mark for each correct row |
| Total | | | | 15 | |

| Question | | | Answer | Marks | Guidance |
|----------|------|------|--|-------|--|
| 5 | (a) | (i) | (upthrust = weight so) $Ad\rho_w g = mg$ ✓ $d = mg/A\rho_w g = m/A\rho_w$ ✓ | 2 | |
| | | (ii) | maximum upthrust = $LA\rho_w g$ and weight of rod = $LA\rho_{rod}g$ ✓ if $\rho_{rod} > \rho_w$ then weight > upthrust so it will sink ✓ | 2 | can be done without algebraic treatment by referring to the maximum upthrust being the weight of a volume of water equal to the volume of the rod ✓ which must be less than the rod's weight if the density of water is greater than that of the rod ✓ |
| | (b) | | upwards force = $\rho_w(d+s)Ag$ and downwards force is still $mg = \rho_w Adg$ ✓ so resultant force $F = \rho_w Asg$ and acceleration = $F/m = \rho_w Asg/m$ ✓ $a \propto -s$ so this is simple harmonic motion ✓ $a = -\omega^2 s$ so $\omega^2 = \rho_w Ag/m$ ✓ $T = 2\pi/\omega$ ✓ (= $2\pi\sqrt{m/\rho_w Ag}$) | 5 | allow reference to additional weight of water displaced when moved from equilibrium. accept in the opposite direction for (-) sign Full credit for corresponding alternative with $2\pi f$ for ω |
| | (c)* | | Level 3 (5–6 marks) Both methods compared and advantages of SP and disadvantages of FR identified. Qualitative comparison of uncertainties of the different methods made, even if not completely successful, linking to value for g . <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Compares both methods and identifies some advantages of SP method. Partial attempt to quantify differences. <i>There is a line of reasoning presented with some structure. The</i> | 6 | Indicative scientific points may include: floating rod method <ul style="list-style-type: none"> • Method is indirect • Rod may oscillate in different directions • Damping will stop oscillations • Difficult to time a large number of oscillations to reduce ΔT • Water surface will move making it hard to judge position of rod • Use of the formula in the form $g = \frac{4\pi^2 m}{T^2 \rho_w A}$ • Percentage uncertainty in m and A are small compared with T |

| Question | Answer | Marks | Guidance |
|----------|--|-----------|--|
| | <p><i>information presented is in the most-part relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Makes direct comparison between at least one shortcoming of FR method and an advantage of SP method. No attempt to quantify uncertainty.</p> <p><i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i></p> <p>0 marks No response or no response worthy of credit.</p> | | <ul style="list-style-type: none"> • T will be of the order of 1 s • $\Delta T/T$ significantly larger than for pendulum • logical argument linking uncertainties in measurement through to value of g <p>simple pendulum method</p> <ul style="list-style-type: none"> • Method is indirect • Can time a large number of oscillations to reduce ΔT • May be systematic error in measuring L • Use of dense bob and light, flexible thread minimises frictional losses • Easy to judge position of bob e.g. passing through centre • Use of the formula in the form $g = \frac{4\pi^2 l}{T^2}$ • T will be of the order of 2s • $\Delta T/T$ significantly smaller than for floating rod • logical argument linking uncertainties in measurement through to value of g |
| | Total | 15 | |

| Question | | | Answer | Marks | Guidance |
|----------|-----|------|---|-------|---|
| 6 | (a) | (i) | Conservation of momentum requires that vector addition of $m_{\alpha}v_1$ & $m_{\text{He}}v_2$ will give $m_{\alpha}u$ ✓ For the masses to cancel $m_{\alpha} = m_{\text{He}}$ ✓ | 2 | allow suitable alternative wording |
| | | (ii) | Pythagoras' theorem gives $(v_1)^2 + (v_2)^2 = (u)^2$ ✓ As $m_{\alpha} = m_{\text{He}} = m$: $\frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2 = \frac{1}{2}mu^2$ ✓ | | |
| | (b) | | Straight line diagonally up to point of pair creation roughly bisecting the 'V' ✓ Gamma is uncharged/not very ionising ✓ e^- and e^+ have opposite charges (so qvB has opposite sign) so they curve in opposite directions ✓ paths are spirals or radius of paths becomes less as they go on ✓ (because) the positron and electron are slowing down ✓ due to energy loss through ionising the air particles (which is why you can see the tracks) ✓ | 6 | 3 rd marking point needs both the observation (paths curve opposite ways) and the inference (particles have opposite charges) allow $r = mv / Bq$ |
| | (c) | (i) | total charge before = 0 (p^+ and p^-) ✓ 4 hadron tracks curve clockwise and 4 anticlockwise, so for every + charge there is a - charge ✓ | 2 | |

| Question | Answer | Marks | Guidance |
|----------|--|-----------|----------|
| | <p>(ii) $mv^2/R = Bqv \checkmark$</p> <p>so $v = BqR/m \checkmark$</p> <p>$= (2.2 \times 1.6 \times 10^{-19} \times 4.6 \times 10^{-3}) / 2.5 \times 10^{-28}$</p> <p>$= 6.5 \times 10^6 \text{ (m s}^{-1}\text{)} \checkmark$</p> | 3 | |
| | Total | 15 | |

| Question | Answer | Marks | Guidance |
|----------|--|----------|--|
| 7 (a)* | <p>Level 3 (5–6 marks) Relates desirable and undesirable properties of aluminium during the launch and in the space environment with explanation in terms of physics principles.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Recognises some desirable qualities of aluminium and some disadvantages with some details relating to the launch or space environment but lacks explanation of either.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Recognises that toughness, strength and low density are advantageous as these qualities make it durable and light but does not relate properties to details of the context.</p> <p><i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i></p> <p>0 marks No response or no response worthy of credit.</p> | 6 | <p>Indicative scientific points may include:</p> <p>Properties of aluminium</p> <ul style="list-style-type: none"> • Low density so light • Strong to withstand stresses e.g. in launch • Tough so will not crack easily • May conduct charge from solar wind into sensors • Changing magnetic field induce emfs in the satellite body which may damage electronics <p>Demands of environment</p> <ul style="list-style-type: none"> • Vacuum of space • Exposed directly to solar storms or solar wind • Changing magnetic fields • Irradiated by UV etc. from Sun • Cannot be repaired once in position • Need to manoeuvre easily • Great stresses during launch |
| | Total | 6 | |

| Question | | Answer | Marks | Guidance |
|--------------|-----|---|----------|--|
| 8 | (a) | $hc/\lambda = kT \Rightarrow T = hc/k\lambda \checkmark$ $T = 6.6 \times 10^{-34} \times 3 \times 10^8 / (\lambda \times 1.4 \times 10^{-23})$ Gives range of 1.4×10^6 K to 1.4×10^8 K \checkmark Compares with T of photosphere, e.g. at least 200 \times higher temperature \checkmark | 3 | Accept other sensible Boltzmann approximations e.g. $3/2 kT$ Accept Boltzmann factor considerations leading to lower temperatures |
| | (b) | Must consider 'worst case scenario', i.e. 3200 km s^{-1} speed \checkmark time to reach Earth = $150 \times 10^9 \text{ m} / 3200 \times 10^3 \text{ m s}^{-1}$ = $46875 \text{ s} = 13 \text{ hours} \checkmark$ Action taken: any one from shut down satellites facing Sun/prepare for power cuts/shield sensitive circuits/disconnect grid circuit breakers \checkmark | 3 | ecf wrong choice of speed must convert to hours or days (to have realistic view of time left) allow other reasonable suggestion |
| Total | | | 6 | |

| Question | Answer | Marks | Guidance |
|----------|---|----------|---|
| 9 (a) | SOHO orbital radius = $(1.50 \times 10^{11} - 1.5 \times 10^9)$ $= 1.485 \times 10^{11} \text{ (m)} \checkmark$ $\omega = 2\pi/T \checkmark$ $= 2\pi/(3.2 \times 10^7 \text{ s}) (= 1.96 \times 10^{-9} \text{ rad s}^{-1}) \checkmark$ $a = (-)r \omega^2 = (1.485 \times 10^{11} \text{ m}) \times (1.96 \times 10^{-9} \text{ rad s}^{-1})^2$ $= (-)5.7 \times 10^{-3} \text{ m s}^{-2} \checkmark$ | 4 | <i>Alternative</i> SOHO orbital radius = $(1.50 \times 10^{11} - 1.5 \times 10^9)$ $= 1.485 \times 10^{11} \text{ (m)} \checkmark$ Speed of SOHO = orbital circumference / time $= 2\pi \times (1.485 \times 10^{11} \text{ m}) / 3.2 \times 10^7 \text{ s} \checkmark$ $= 29000 \text{ m s}^{-1} \checkmark$ $a = v^2 / r = (29000 \text{ m s}^{-1})^2 / (1.485 \times 10^{11} \text{ m})$ $= 5.7 \times 10^{-3} \text{ m s}^{-2} \checkmark$ |
| (b) | Net F_{grav} on SOHO = $(-)Gm(M_S/r_S^2 - M_E/r_E^2) \checkmark$ $= (-)11 \text{ N} \checkmark$ From (c) centripetal force = mass SOHO x centripetal acceleration $= 1900 \text{ kg} \times ((-)5.7 \times 10^{-3}) \checkmark$ $= (-)11 \text{ N} \checkmark$ net gravitational force provides the centripetal force required to enable SOHO to orbit in 1 Earth year \checkmark | 5 | ecf from (c) as necessary. ORA |
| | Total | 9 | |

| Question | Answer | Marks | Guidance |
|----------|--|-------|----------|
| 10 | Conservation of energy i.e. $\Delta GPE = \Delta KE$ ✓ $G M m (1/r_{\text{closest}} - 1/r_{\text{furthest}}) = \frac{1}{2} m (v_{\text{closest}}^2 - v_{\text{furthest}}^2)$ $3.29 \times 10^{23} \text{ J} = (1.1 \times 10^{14}) (v_{\text{closest}}^2 - 880^2)$ ✓ $v_{\text{closest}} = 54\,000 \text{ m s}^{-1}$ ✓ which is 62 times greater than 880 m s^{-1} ✓ | 4 | |
| | Total | 4 | |

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