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June 2022

GCSE Astronomy 1AS0 02

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June 2022

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Introduction

The GCSE Astronomy examination continues to be centred around non-tiered examination papers, with the 3½ hours of examination time split between two papers:

- Paper 1 – Naked-eye Astronomy
- Paper 2 – Telescopic Astronomy

The subject content of each paper mirrors a similar division of material within the Specification.

The central focus on observational astronomy was very evident in these examination papers, where many questions were designed around presenting candidates with the results of an astronomical observation. Candidates were asked to process the information and arrive at scientific conclusions.

Others questions asked them to comment on the conclusions that others, such as archaeoastronomers, have placed on astronomical data.

Uniquely amongst the scientific subjects studied at GCSE level, Astronomy allows candidates to experience working with a truly observational science, where some of the most incredible scientific advances in human history have been made, despite the fact that basic scientific strategies such as control of variables are usually impossible.

The 2022 examination papers represented a very welcome return to a structure where candidates were able to express their full knowledge and understanding in the two full examination papers, supported by the guidance from the Advance Information documents.

It is clear from this year's examination that centres and their candidates have worked extremely hard on their astronomical studies, despite the inevitable disruption from the unprecedented events of recent years.

The enthusiasm and commitment, which have always characterised those involved with the teaching and learning of GCSE Astronomy, continue to be evident. Centres and their candidates are to be commended for the conspicuous hard work and dedication (often as part of an extra-curricular provision), which clearly went into the preparation of this year's cohort.

Across both examination papers, this year's candidates demonstrated a number of impressive qualities, reflecting high quality teaching and learning throughout their courses:

- Candidates continue to show good flexibility when dealing with the wide range of data that the subject generates
- Many candidates coped very well with the often very demanding mathematical skills required by the questions in this year's papers, including skills such as squaring, cubing and logarithmic scales
- Strong graphical skills were demonstrated in both the creation and use of graphs.

Many candidates showed excellent background knowledge in the subject, allowing them to enhance the depth and detail of their answers.

It was evident that, for some candidates, questions on some topic areas were rather unexpected. Centres are reminded of the need for candidates to have been exposed to all parts of the Specification before the examination.

Comprehensive Topic Support Guides have been produced to support teaching and learning in several areas and these can be downloaded from the GCSE Astronomy pages of the Pearson website. As well as providing detailed subject background, they contain worked examples and practice examination questions.

Question requirements

Although it may seem an obvious point, it is clear that significant numbers of candidates are losing marks because they have not understood the requirements of the question fully. In particular, candidates must pay close attention to the Command word used at the start of each question, because these invariably determine the structure of the mark scheme.

- Questions that ask candidates to Explain will not award any marks for a description. When answering these questions candidates must be clear that they are explaining **why** something happens and not simply describing **what** happens. Candidates should ensure that their answer gives material additional to that in the question and that they are not just repeating the question.
- Questions that ask candidates to 'Compare…' will require both sides of the particular argument to be stated for full marks.
- Questions that ask candidates to 'Evaluate…' will require them to come to a judgement or conclusion, after having looked at both sides of the information presented.
- Questions that ask candidates to 'Show…' will award marks for each step of astronomical reasoning in the working. Marks will not be awarded for unexplained numbers or calculations.

Diagrams

By the nature of the subject, almost every GCSE Astronomy examination question involves the use of a diagram either in the question, the answer or in the mind of the candidate answering it.

- Most concepts in astronomy are expressed more clearly using a diagram. Candidates are advised to use a fully-labelled diagram whenever it will make their answer clearer. Obviously, a diagram is required by the mark scheme in questions that state 'Use a diagram…'. Although it is optional in questions stating 'You may use a diagram…' ,it is still strongly recommended. The use of diagrams to clarify answers was definitely a hallmark of the higher-achieving candidates in this examination.
- It is essential that all the key parts of a diagram are labelled clearly. A number of 'diagrams' seen by this year's Examiners contained lines and curves representing important items but which had no label, often rendering the diagram insufficient for the award of marks.
- Candidates are advised to use a ruler whenever possible in their diagrams. Diagrams drawn without the use of a ruler can easily descend into becoming rough sketches
- Diagrams in GCSE Astronomy often involve drawing an area of the night sky. Given its apparently 'domed' appearance, candidates should practise drawing it beforehand, because it can present a drawing challenge. Nevertheless, regarding each small section of the sky as a piece of flat graph paper, with lines drawn with a ruler and labelled clearly, can make this a more straightforward task.

Calculations

In both examination papers, calculations often represent a significant number of marks and it is important that each candidate shows the full extent of their ability in these questions.

- Candidates must bring an adequate calculator to both examination papers so that they can meet all its mathematical demands. As well as basic arithmetical functions, astronomical calculations can often involve more complex operations such as squaring, cubing, taking logarithms etc.
- Candidates should ensure that they are familiar with the operation of their chosen calculator.
- Given that some calculations are now worth three or even four marks, the provision of clear, structured working is more important than ever.
- The provision of clear working is essential in questions that require candidates to 'Show…' rather than 'Calculate…'. In these questions, there are obviously no marks for the final answer (given on the paper) and all marks are for the steps in the working and their astronomical justification.
- It is recommended that candidates give their final answers to a sensible number of significant figures. They should take their cue from the data given in the question, in addition to the precise answer resulting from their calculation.

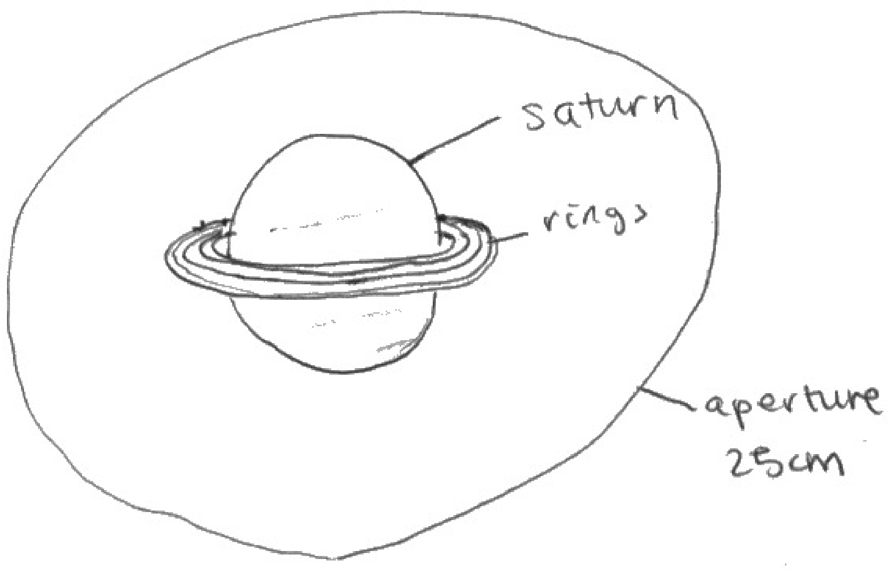
- Questions asking candidates to 'Analyse…' will require them to use the numerical data provided within the question as part of their answer. These data can be provided in a table, graph or other form but must be used in the candidates' calculations, if full marks are to be obtained.

Question 1 (c)

This question provided a highly accessible mark for almost all candidates, who had simply to indicate that they were aware of a prominent ring structure around the planet Saturn. Those candidates with more experience of observing through a telescope of this aperture showed a little more detail in their sketches, normally by indicating some structure within the rings.

(c) Draw the appearance of the planet Saturn, when viewed through a telescope with an aperture of 25 cm.

(2)



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Examiner Comments

This sketch gains both marks: it shows an indication of structure within Saturn's rings.

Total: 2 Marks

Question 3 (b)(i)

Almost all candidates were aware of Galileo's discovery of the four largest moons orbiting Jupiter.

However, some did not respond to the focus of the question, which asked them to explain how it provided evidence that not all celestial objects orbited the Earth.

The second mark, for pointing out that these four moons did not orbit the Earth, was thus not gained by all candidates.

(b) In 1609 Galileo Galilei made observations of the night sky using a small telescope. His observations were evidence that the Sun and the planets did **not** orbit the Earth.

(i) Galileo made drawings of four moons orbiting the planet Jupiter, as shown in Figure 4.

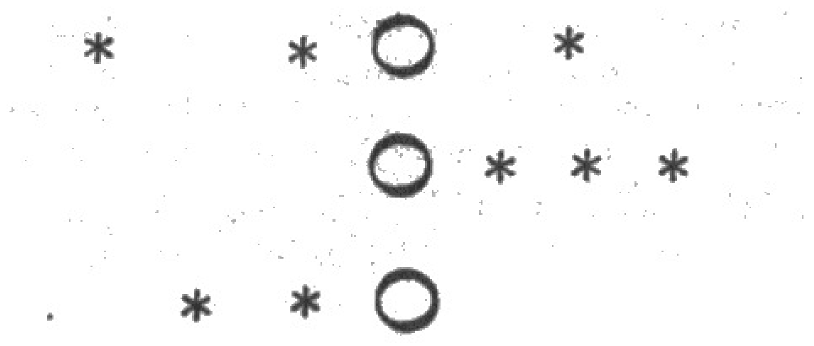

Figure 4

Explain how Galileo used the drawings in Figure 4 as evidence that the Sun and planets did **not** orbit the Earth.

(2)

Because the moons are orbiting jupiter and not Earth

ResultsPlus
Examiner Comments

This response very concisely gains both marks available for this question.

Total: 2 Marks

Question 3 (b)(ii)

In a similar way to Question (Q) 3(b)i, although most candidates seemed to be aware of Galileo's discovery of the 'phases of Venus' , a much smaller proportion understood that it is the changing size of Venus during its phase cycle that makes it an important piece of evidence against a geocentric theory of the solar system. Venus' widely varying apparent **size** shows that its distance from the Earth is also widely varying, which is inconsistent with a (circular) orbit.

Many candidates focussed on explaining the phases of Venus in terms of the changing angle between the Sun, Venus and the Earth, which was not required in this question.

(ii) Galileo made drawings of the changing appearance of the planet Venus, as shown in Figure 5.

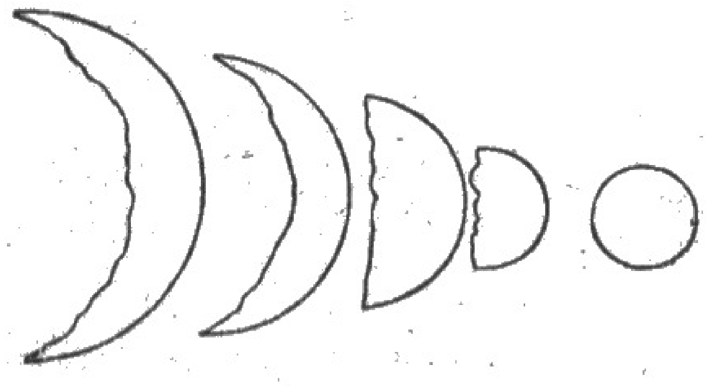

Figure 5

Explain how Galileo used the drawings in Figure 5 as evidence that the Sun and planets did **not** orbit the Earth.

(2)

Because the shadow on venus is caused by light from the sun being blocked from a face of the planet so the fact that the shadow changes shows that ~~that~~ Venus is moving around the sun.

ResultsPlus Examiner Comments

This response focusses on the changing **phase** of Venus, which does not provide evidence that Venus orbits the Sun. The Moon, for example, shows phases whilst orbiting the Earth.

The key difference is that the lunar disc essentially remains the same **size** during the lunar phase cycle, supporting the view that the Moon is in a (circular) orbit around the Earth.

Total: 0 Marks

Question 3 (b)(iii)

Although to twenty-first century eyes these drawings might seem irrelevant to the geocentric view of the solar system, in Galileo's time their publication cast very significant doubt on the view that the Earth was the centre of the solar system.

In the geocentric view, the Earth was obviously the only place that humans could inhabit. Consequently, the observation of 'Earth-like' features such as mountains and valleys on the Moon suggested that the Earth might not be the only possible 'centre' for the solar system.

(iii) Galileo made drawings of the appearance of the Moon's disc, as shown in Figure 6.

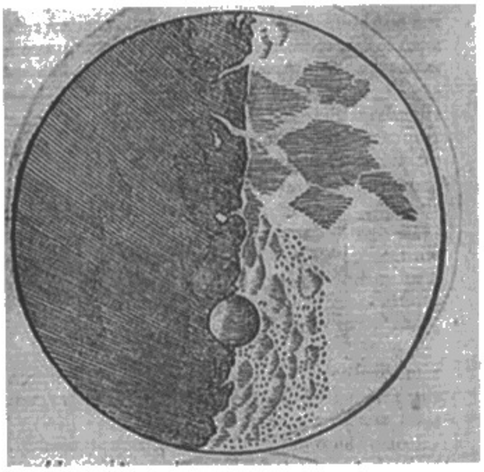

Figure 6

Explain how Galileo used the drawing in Figure 6 as evidence that the Sun and planets did **not** orbit the Earth.

(2)

The moon would not have phases like this, when half of it is in sunlight, is both the Sun and moon orbitted Earth. It shows only the moon is orbitting Earth

ResultsPlus
Examiner Comments

In common with the responses of many candidates, this answer focusses on the formation of phases, even though they are possible in both geocentric and heliocentric models of the solar system.

Total: 0 Marks

Question 3 (c)

Almost all candidates used the data in Table 1 to point out that twenty-first century telescopes have larger apertures and longer focal lengths than those used in 1609.

Many then pointed out that this would give modern astronomers 'better' images. A smaller portion went on to gain the second mark in this question by including a specific image quality, such as resolution or faintness of objects observed.

(c) Four hundred years after Galileo, twenty-first century astronomers use telescopes to produce much higher quality images of Jupiter, Venus and the Moon.

Table 1 shows some information about these telescopes.

	Galileo's telescope (1609)	Twenty-first century telescope
Aperture	3.5 cm	11 m
Focal length	98 cm	17.5 m

Table 1

Analyse the data in Table 1 in order to explain how the images from twenty-first century telescopes are better than those obtained by Galileo in 1609.

(2)

Because the 21st century telescope has a much larger aperture, it will have a higher resolution and the higher focal length means a higher magnification

(Total for Question 3 = 9 marks)

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Examiner Comments

This response comfortably gains both marks because it identifies properties of the telescopes which have improved (aperture and focal length), as well as the resulting impact on images (resolution and magnification).

Total: 2 Marks

Question 4 (b)(i)

Once again, the first mark in this question proved very accessible to all.

Candidates needed simply to show a planet moving in front of a star, as viewed by an observer on Earth, to gain the mark.

The second mark was gained by linking this ‘transit’ with the central dip in the brightness graph in Figure 7.

As with many questions in the GCSE Astronomy examination, both marks could be achieved very simply with the use of a clearly-labelled diagram, as prompted by the question stem!

A number of candidates attempted (unsuccessfully) to gain the two marks by means of an extensive written response or using a diagram that simply comprised two unlabelled circles.

(b) One method for finding planets orbiting other stars is to take very careful measurements of the star's brightness as the planet transits the star.

Figure 7 shows a set of measurements taken in this way.

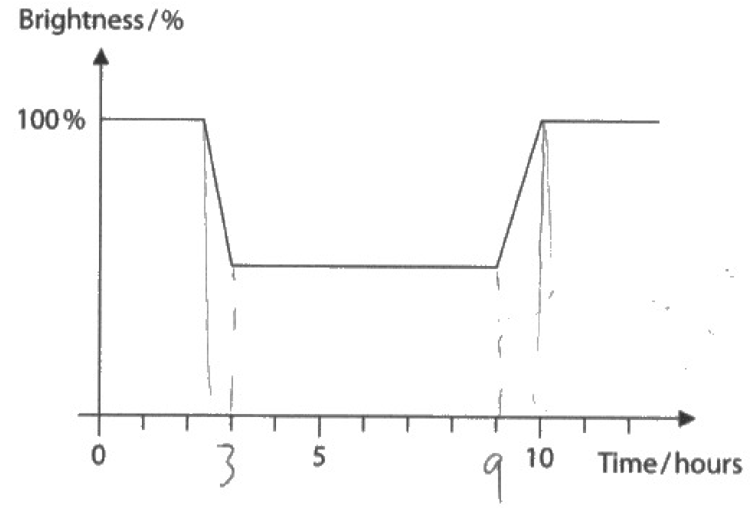

Figure 7

(i) Explain the shape of the graph in Figure 7.

You may include a clearly labelled diagram in your answer.

(2)

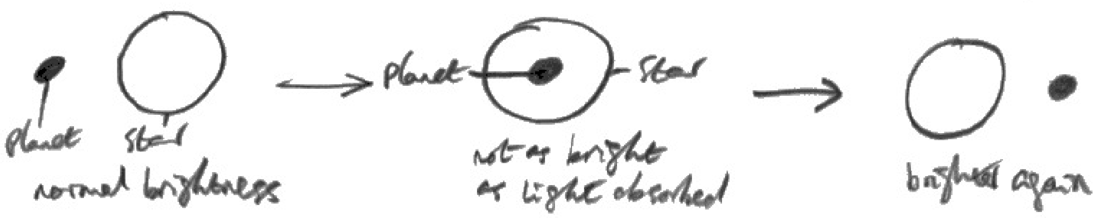

Figure 7 shows that a stars brightness decreases as a planet transits it and absorbs some light from it.

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Examiner Comments

This response gains both marks because it shows the exoplanet passing in front of the stellar disc and identifies this with the drop in brightness in Figure 7.

Total: 2 Marks

Question 4 (b)(ii)

Although it was clear from responses to Q4(b)ii that most candidates understood that the dip in brightness in Figure 7 was caused by an exoplanet passing in front of its star, the majority of candidates believed that the size of the exoplanet was related to the width of the dip in the brightness graph.

Only a small proportion of candidates seemed to have a full understanding of how the 'transit method' can be used to determine the diameter of the orbiting exoplanet, using the time difference between first and second (or third and fourth) contact points on the graph. In Figure 7 this was conveniently arranged to be one hour, giving a planetary diameter of 140 000km.

Sadly, a few candidates who had performed the correct calculation lost a mark by not including the correct unit – kilometres.

(ii) The planet is known to be travelling at 140 000 km per hour in its orbit.

Evaluate the information in Figure 7 in order to estimate the diameter of the planet.

(3)

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{distance} = \text{speed} \times \text{time}$$
$$= 140\ 000 \times 5$$
$$= 700000$$

Diameter of planet = 700000 km

ResultsPlus
Examiner Comments

Although this candidate uses the incorrect time interval from Figure 7, they show all the stages in their working and thus gain one mark for their incorrect answer.

Total: 1 Mark

Question 4 (c)

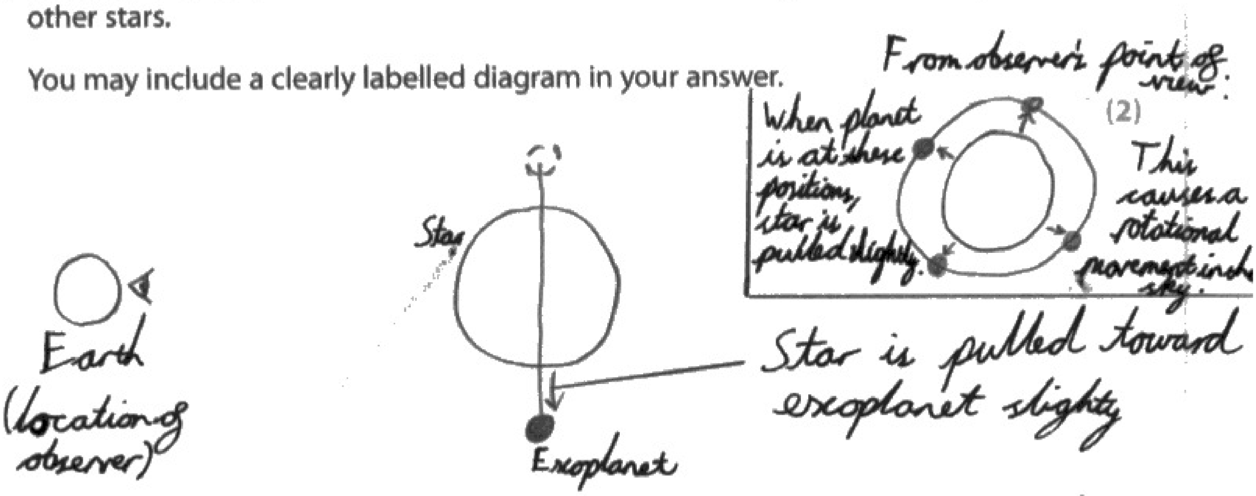
Many candidates seemed only to have revised the transit method for finding exoplanets and thus had difficulty in gaining either of these straightforward 'recall' marks.

Once again, the higher quality responses always included a clearly-labelled diagram, because many of the concepts involved are extremely hard to convey using text alone.

(c) Describe a **different** method that astronomers use to find planets orbiting other stars.

You may include a clearly labelled diagram in your answer.

(2)



Astronomers use astrometry, where a planet is detected (if it is not side-on to Earth) by the 'wobble' its gravity ~~the~~ causes on the star it orbits.

ResultsPlus Examiner Comments

This candidate identifies another method for detecting the presence of exoplanets – astrometry.

Sensibly , they have chosen to support their description of the method with a labelled diagram, ensuring that their answer gains both marks.

Astrometry is an example of an astronomical technique that is very difficult to explain clearly by means of text alone. Many candidates who attempted to describe astrometry without a diagram achieved only one mark, as a result.

Total: 2 Marks

Question 5 (b)(i)

This question was well-answered, with most candidates identifying the stronger gravity and thicker atmosphere of Earth as key factors, along with the much smaller payload of the return part of the mission.

It was pleasing to see specific astrophysical terms such as 'escape velocity' included in many answers.

Along with many others in the GCSE Astronomy examination, this question is an example of where the use of correct scientific terminology helps to increase the mark awarded.

(i) Explain why the launch from the Earth required a much more powerful rocket than the launch from the Moon.

(2)

Earth's gravity is greater than the Moon's. This means the escape velocity of the Earth is also greater so much more powerful rockets are needed to launch from the Earth in comparison to the Moon

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This candidate's answer is focussed on the exact requirements of the question.

It explains why the stronger gravity on the Earth will require more powerful rockets when launching the Apollo mission, as well as using scientific terms correctly, such as 'escape velocity'.

Total: 2 Marks

Question 5 (b)(ii)

A wide range of factors could be used to gain this mark, such as the rotation of the Earth or Moon and the revolution of the Moon around the Earth. Some candidates were aware that the minimum energy trajectory between the two points will be curved, due to the presence of the gravitational field between the Earth and the Moon.

Figure 11 shows the Earth and the Moon, with the Apollo 11 launch and landing sites labelled.

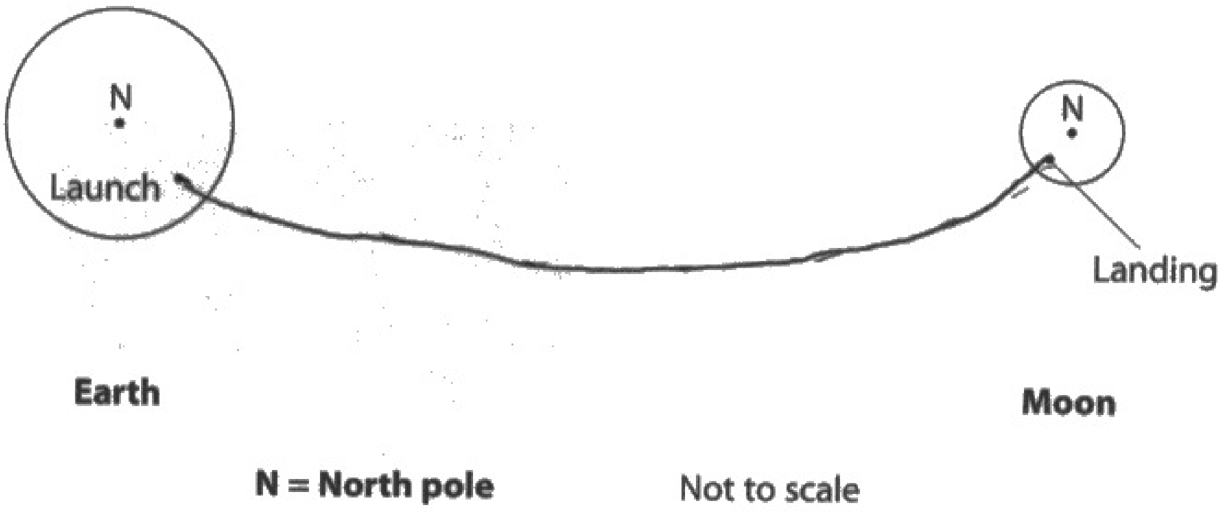

Figure 11

(ii) Explain why the Apollo 11 mission did not travel in a straight line between its launch and landing sites.

(1)

The curved path allowed for the moon to move further around its orbit.

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This candidate gains the mark by pointing out that the Moon is constantly in motion around the Earth.

Total: 1 Mark

Question 5 (b)(iii)

Although the previous question was intended to prompt candidates that a straight line would not be the correct answer, a number of straight line paths were, nevertheless, submitted.

Most candidates suggested a smooth curved path between Launch and Landing sites.

Because the Apollo missions are mentioned in the Specification, some candidates evidently had studied a little more detail on their trajectories. They gained all three marks, by including the gravity-assist around the Earth, and orbit around the Moon, in their answers.

Figure 11 shows the Earth and the Moon, with the Apollo 11 launch and landing sites labelled.

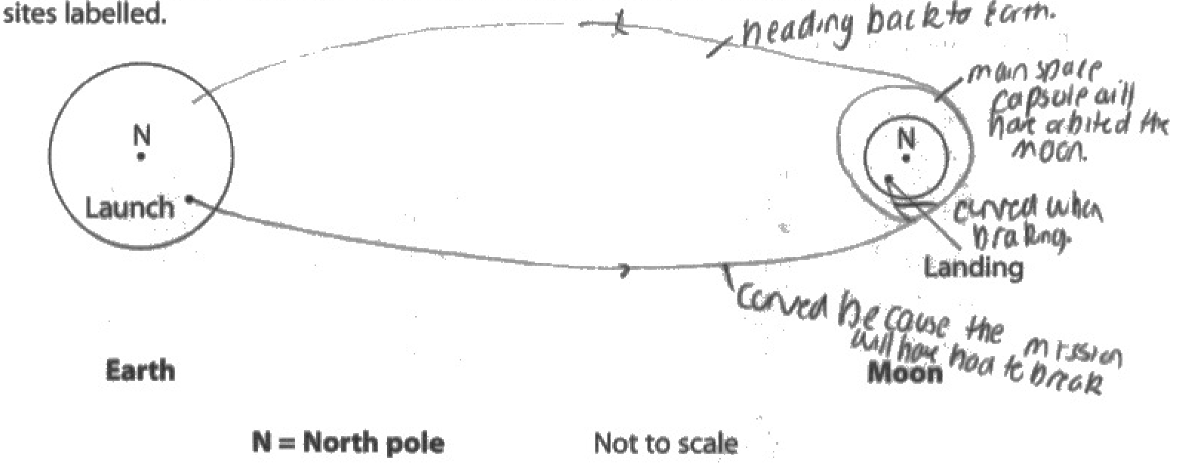

Figure 11

(ii) Explain why the Apollo 11 mission did not travel in a straight line between its launch and landing sites.

(1)

It will have had to break in order to get into orbit then land on the moon also the moon is moving in the orbit so the mission will have had to take a curved path to meet it.

(iii) Draw the path taken by the Apollo 11 mission on Figure 11.

(3)

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This candidate's response is given two marks.

As well as the smooth curve between the Earth and the Moon, it shows an orbit of the Moon before landing.

Total: 2 Marks

Question 5 (c)

This question was well-answered, with most candidates being able to recall at least one piece of information obtained by the Apollo missions.

The composition of the surface rocks and their link to the Giant Impact Hypothesis was the most popular response.

Some candidates lost marks by giving very vague answers such as 'its structure', 'its orbit', 'surface conditions' etc.

(c) The Apollo missions provided astronomers with new information about the Moon.

State **two** pieces of new information about the Moon provided by the Apollo missions.

(2)

1 Analysis of lunar rocks and traces of water.

2 Earth to Moon distance could be calculated using radar.

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Examiner Comments

Two specific measurements were required for full marks in this question.

Total: 2 Marks

Question 6 (a)

The different compositions of the Earth and Jupiter were widely understood by the majority of candidates as the cause of Jupiter's comparatively low mass.

Although this was sufficient for the award of the two marks, some candidates were also able to talk about the planets' differing densities.

Jupiter is 1300 times larger than the Earth.

Its mass is only 318 times as much as the Earth's.

Explain why Jupiter does **not** have a mass 1300 times as much as the Earth's.

(2)

It's composed of gases whereas earth is composed by rock and metal, which have a greater mass than gases (Hydrogen & Helium mostly)

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Examiner Comments

Jupiter's gaseous composition and the Earth's rocky composition are expressed clearly, here.

Total: 2 Marks

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Examiner Tip

The highest quality answers recognised our planet's unique status and rewarded it with a capital letter! ('Earth' not 'earth')

Question 6 (b)(i)

Generally, this year's cohort of candidates showed a good understanding of the objects shown in Figure 13.

Almost all candidates were clear that 'X' was the shadow of a moon, rather than a physical feature on Jupiter. However, only a very small proportion of candidates realised from very careful inspection of the photograph in Figure 13 that Europa was illuminated from the top right of the picture, meaning that the shadow at 'X' must be cast by another moon not included in the picture.

(b) Europa is one of the moons of Jupiter.

Figure 13 is an image of Europa orbiting Jupiter, taken by the Voyager 1 probe.

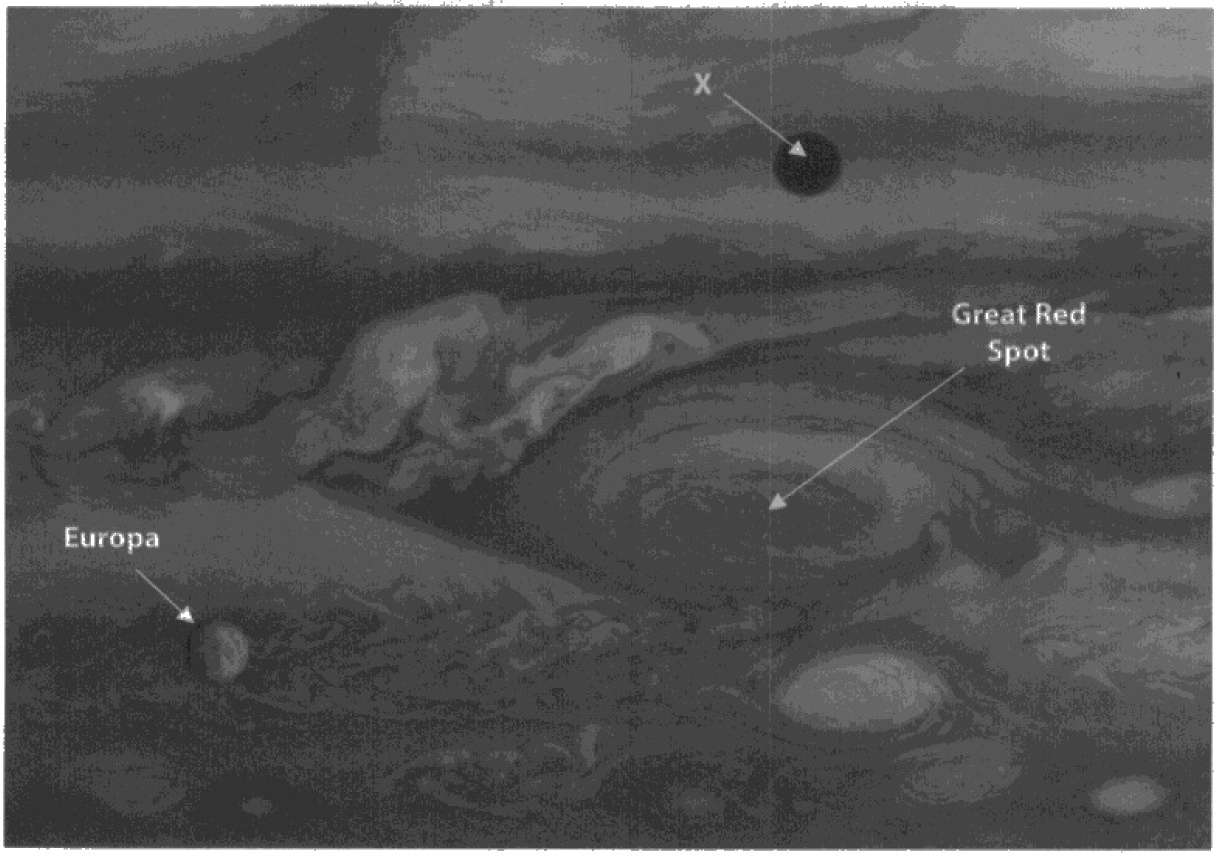

Figure 13

(i) Explain the cause of the dark circle labelled 'X' in Figure 13.

(2)

A moon casting a shadow on Jupiter's surface from behind Voyager 1's orbit of Jupiter, such as Ganymede.

Only a very few candidates pointed out that the direction of illumination of Europa and the position of the shadow at 'X' were inconsistent. The shadow must, therefore, have been cast by another moon of Jupiter.

The name of the second moon was obviously not required in this question.

Total: 2 Marks

Question 6 (b)(ii)

Most candidates were able to suggest some of the physical properties of the Great Red Spot, such as its gaseous nature or the idea that it is believed to be a large storm in Jupiter's atmosphere.

Obviously candidates who stated that it was 1.Great and 2.Red gained no marks.

(ii) Jupiter's Great Red Spot is also labelled in Figure 13.

The Great Red Spot is a large, reddish-coloured spot, first observed in 1878.

State **two other** physical properties of the Great Red Spot.

(2)

1 made of gas

2 It is a Storm

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Examiner Comments

This candidate, very concisely, lists two physical features of Jupiter's Great Red Spot.

Other successful answers referred to the high speed winds involved or its great size – comparable with that of the Earth.

Total: 2 Marks

Question 6 (b)(iii)

Although many candidates gained a mark on this question by stating that telescopes on the Earth were unable to image the Great Red Spot until 1878, a number did not explain that this was caused by insufficient aperture, resolution or magnification. Often they stated simply that 'telescopes were not good enough' (= 1 mark).

(iii) Explain why the Great Red Spot was **not** observed until 1878.

(2)

The telescopes were not powerful enough to resolve the ~~great~~ Great Red Spot. They also didn't have enough magnification as lenses and mirrors were too small.

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This response identifies inadequacies in nineteenth-century telescopes as the cause, and includes specific astronomical terms such as 'resolution', to gain both marks on this question.

Total: 2 Marks

Question 6 (c)

Unsurprisingly, as the largest planet in the solar system, Jupiter plays a prominent role in almost all theories of the formation of the solar system.

Although there is still much debate in this area of the subject, the award of marks in this question required candidates simply to list features that can be explained successfully, such as those listed in the Mark Scheme.

(c) Some astronomers have suggested that, since the formation of the Solar System, Jupiter has changed its position amongst the other planets.

Give **two** pieces of evidence for this suggestion.

(2)

1 It is much Closer than the rest of the gas giants

2 It has the largest mass and so is the most likely to move toward the gravitational pull of the Sun. As gravitational forces are greater on larger masses.

(Total for Question 6 = 10 marks)

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This candidate describes the fact that giant gas planets such as Jupiter are thought to form further from the Sun than its current position – a clear piece of evidence that Jupiter has changed its position during the life of the solar system.

The second point seems to be referring to the fact that Jupiter is the most massive planet in the solar system which, on its own, is insufficient for the award of a mark.

Total: 1 Mark

Question 7 (a)(i)

Section 7(a) of the examination paper required a straightforward calculation, followed by a more demanding calculation, on a scale model of the solar system.

Since the model used a very simple scale of 1cm = 1AU, this first calculation simply required candidates to look up the mean orbital radius of Neptune from the Formulae and Data Sheet (30AU) and then transpose it into centimetres.

Since the unit (cm) was supplied on the paper, just the number 30 was required for the award of this mark.

7 (a) A student makes a scale model of the Solar System.

He places the models of the Earth and the Sun 1 cm apart.

(i) Calculate the distance from the model of the Sun to the point where the model of Neptune should be placed.

Use information from the Formulae and Data Sheet.

Give your answer in cm.

(1)

1cm = 1 AU

Nuptune = 30AU = 30cm

Distance from model of Sun = 30cm cm

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Even though working was not required in this question, this candidate has accompanied their answer with clear and labelled working – an example of excellent practice.

Total: 1 Mark

Question 7 (a)(ii)

Although this question used the same simple 1cm = 1AU scale as Q7(ai), it was complicated by the fact that the distance was given in light years.

Consequently, this question had an additional mark for converting 0.8 l.y. into AU, followed by a mark for scaling into centimetres.

The final answer of around half a kilometre demonstrates the immense size of the outer reaches of the Sun's gravitational influence.

Re-creating a scale model of the solar system on this scale could therefore be an effective learning activity for candidates studying GCSE Astronomy. Even the outer reaches of the Kuiper Belt would only be half a metre from the Sun on this scale.

Although not assessed in this question, the appropriate number of significant figures in a numerical answer can be accessed by looking at the numbers given in the question.

Six significant figures is unlikely to be the correct number in any GCSE question.

(ii) The most distant objects in the Oort Cloud are thought to orbit approximately 0.8 l.y. from the Sun.

Calculate the distance from the model of the Sun to the point where the model of an Oort Cloud object should be placed.

Use information from the Formulae and Data Sheet.

(2)

$1AU = 1.5 \times 10^8$ Km

$1Ly = 9.5 \times 10^{12}$ Km

$9.5 \times 10^{12} \times 0.8 = 7.6 \times 10^{12}$

$7.6 \times 10^{12} \div 1.5 \times 10^8 = 50666.6$ AU

Distance from model of Sun = 50666.7 cm

ResultsPlus
Examiner Comments

This is a correct answer, accompanied by clear and labelled (although rather diagonal) working – excellent examination technique.

Total: 2 Marks

Question 7 (b)(i)

Section 7(b) presented candidates with information about Johann Bode's simple number pattern, which models very closely the orbital radii of some of the major planets in the solar system.

The first question (Q7(b)i) simply required candidates to look up the relevant orbital radii from the Formulae and Data Sheet and then subtract them from the predictions of Bode's number pattern.

Although at the time Bode proposed his law, the orbital radius of 2.8AU was thought to be empty, almost all candidates were aware that this coincides closely with the mean orbital radius of the Asteroid Belt.

A few candidates subtracted Bode's predicted radii from the actual radii, to obtain negative numbers in the Difference column. Although the sign of the numbers in the Difference column is arbitrary, the others in Table 3 show clearly the system being used in this example.

Name	Bode's prediction (AU)	Actual radius of orbit (AU)	Difference (AU)
Mercury	0.4	0.38	0.02
Venus	0.7	0.72	–0.02
Earth	1.0	1.0	0
Mars	1.6	1.5	0.1
Ceres	2.8	2.8	0
Jupiter	5.2	5.2	0
Saturn	10	9.5	0.5
Uranus	19.6	19.1	0.5
Neptune	38.8	30.0	8.8

Table 3

(i) Complete Table 3 by filling in the missing **name** and **numbers**.

Use information from the Formulae and Data Sheet.

(3)

ResultsPlus
Examiner Comments

This response shows a full set of correct answers, correctly looked-up and subtracted.

Total: 3 Marks

Question 7 (b)(ii)

As illustrated by the Indicative Content in the Mark Scheme, there is a rich vein of material to be discussed when evaluating the success of Bode's Law.

From some striking similarities (Mercury to Saturn), there followed some impressive 'predictions' (Asteroid Belt and Uranus) along with some disappointing results (Neptune). Even candidates who had not come across Bode's Law before, therefore, had much to evaluate.

The majority of candidates were able to provide a clearly-expressed piece of extended writing that was comfortably within Level 2 (3 or 4 marks) on the Mark Scheme. Those covering a number of points within the Indicative Content were thus awarded the higher of these two marks (4).

(ii) It has been suggested that Bode's number pattern matches the actual radii of the orbits of the planets.

Evaluate this statement using the data in Table 3.

(6)

It is fair to say Bode's number pattern does match the actual radii of the orbits of planets to some extent. He is only correct exactly for 3 planets out of 9 objects. However Bode's number is out of place by minimal numbers such as 0.02 for Mercury. The exceptions are Saturn, Uranus and especially neptune where Bodes number is wrong by 0.5 AU and 8.8 AU for Neptune which is very large error. So in conclusion as Bodes number only matches that of 3 planets actual radii it is wrong to say that his number matches the actual radii of the orbits of planets

ResultsPlus
Examiner Comments

This candidate presents a clearly-expressed piece of writing (Level 2). They make full reference to the data in Table 3 and identify a number of points from the Indicative Content.

Total: 4 Marks

Question 8 (a)

Almost all candidates were aware that X-rays do not pass through the Earth's atmosphere.

Many completed the full explanation by adding that satellites place telescopes above the atmosphere.

8 Figure 14 is an X-ray image of the night sky. The image was taken using the eROSITA X-ray telescope, on board a satellite orbiting the Earth.
Light areas indicate bright X-ray sources and darker areas indicate weaker X-ray sources.

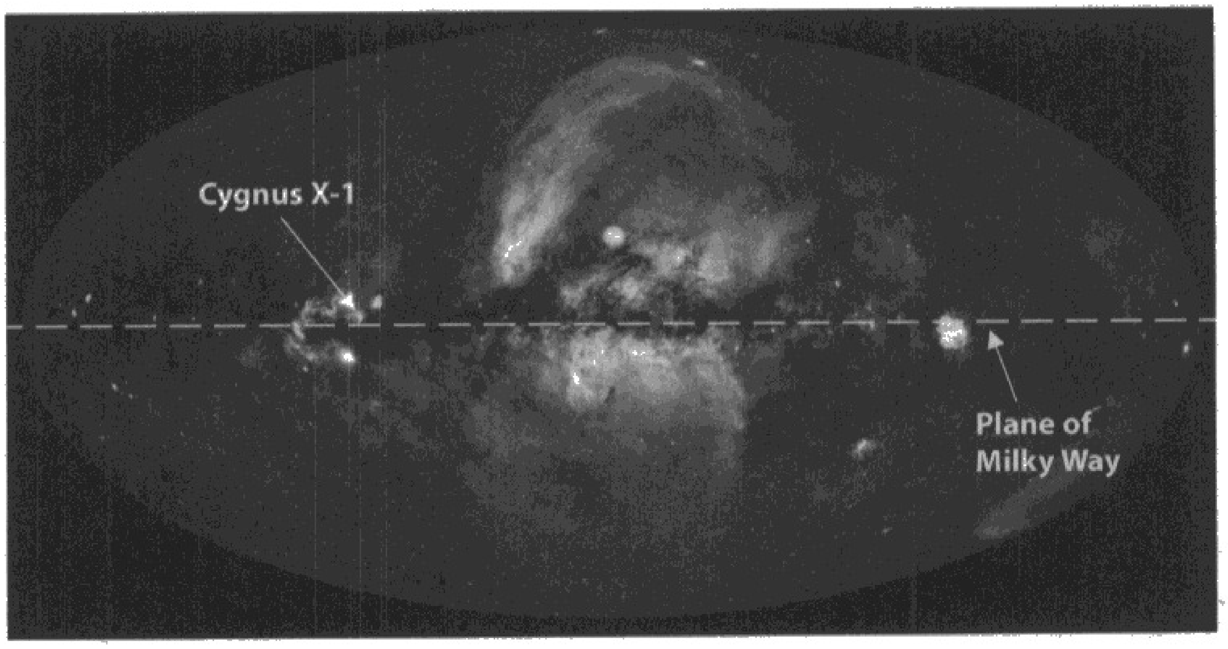


Figure 14

(a) Explain why the image in Figure 14 needed to be taken from a satellite.

(2)

The earth's atmosphere completely blocks any form of X-Rays, meaning telescopes wanting to observe this part of the spectrum must be situated in space where the atmosphere has no effect

ResultsPlus
Examiner Comments

Both points on the Mark Scheme are expressed clearly in this answer.

Total: 2 Marks

Question 8 (b)(i)

The vast majority of candidates were aware that a black hole has an escape velocity greater than the speed of light and will thus not emit any waves from the electromagnetic spectrum.

Candidates who expressed the same idea in simpler terms by commenting on the black hole's incredibly strong gravity, were also awarded this mark.

(b) The very bright X-ray source called Cygnus X-1 is labelled in Figure 14.
Cygnus X-1 is believed to be a binary star system containing a black hole.

(i) State the physical property of a black hole that makes it impossible for it to emit X-rays.

(1)

They allow no E-M radiation to escape / ~~so~~ do not radiate E-M waves due to extremely strong gravitational pull.

ResultsPlus
Examiner Comments

The incredibly strong gravitational field created by a black hole was widely reported by this year's candidates, as this response shows.

Total: 1 Mark

Question 8 (b)(ii)

Candidates had been told that Cygnus X-1 is believed to be a binary system, by the question.

In order to gain the first mark they were expected to realise that, since one of the components was a black hole, it would look very different from a binary system of two similar mass components. Consequently, those candidates who described a binary system of two similar mass components were not awarded the first mark from the Mark Scheme.

Another common misconception was that the black hole, rather than the material being accelerated towards it, would emit the X-rays and this cost some candidates the third mark.

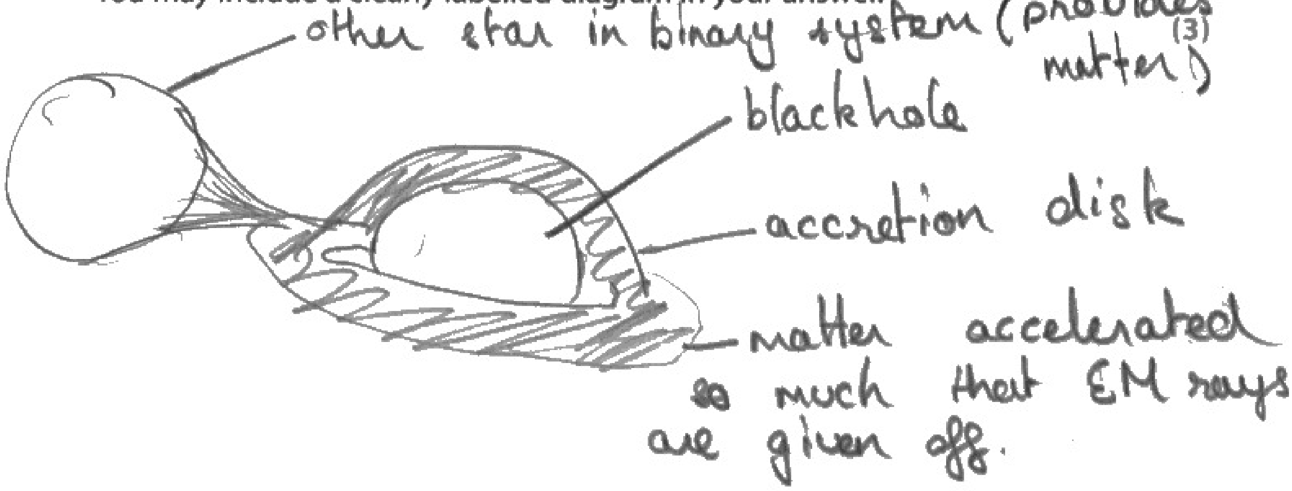
This was another question where a 'clearly labelled diagram' (as prompted in the question) was almost an essential requirement for a top-quality answer. Trying to describe the mechanism for X-ray emission in the Cygnus X-1 system purely by the use of text is a technique to be discouraged.

This response illustrates how effective a clearly-labelled diagram can be, in conveying detailed information, compared with a paragraph of text.

(ii) Explain how the Cygnus X-1 system is such a bright emitter of X-rays.

You may include a clearly labelled diagram in your answer.

(3)



The black hole's strong gravity pulls in material from the other star, creating an accretion disk which matter is accelerated so much that it emits electromagnetic waves like X-rays. It is close by (in plane of milky way) so the

ResultsPlus Examiner Comments

This is an impressive attempt at a detailed diagram of the Cygnus X-1 system, showing a stellar mass companion to the black hole and an accretion disc of accelerated material emitting X-rays.

Total:3 Marks

Question 8 (c)(i-cii)

A simple inspection of the image in Figure 14 shows that the centre of the galaxy produces the strongest X-ray emission.

Most candidates were able to explain this in terms of the greatest density of stars, whilst others went on to refer to the supermassive black hole believed to exist there.

plasma jets will form which also release lots of x-ray's

(c) (i) State the part of the Milky Way galaxy that is most likely to be the brightest X-ray source.

(1)

galactic core ~~central black hole~~

(ii) Explain your answer to (c)(i).

(2)

- the galactic core contains a supermassive blackhole
- a supermassive black hole will have an accretion disc which will release lot's of x-rays and ~~this is~~ it

ResultsPlus
Examiner Comments

As well as identifying the galactic core correctly, this response provides an excellent explanation in terms of the supermassive black hole and accelerated material, such as an accretion disc.

Total: 3 Marks

Question 8 (d)

Since a wide range of luminous objects in the universe produces X-rays, almost all candidates were able to supply at least one celestial object for this question.

(d) Cygnus X-1 and the Milky Way galaxy are sources of X-rays.

State **two other** astronomical sources of X-rays.

(2)

1 Quasars

2 Andromeda Galaxy

ResultsPlus
Examiner Comments

This response gives two examples of specific objects that are strong emitters of X-rays.

Total: 2 Marks

Question 9 (a)

This question examined candidates' ability to assess the suitability of a piece of observing equipment for observing a particular astronomical object, in this case, the Sun.

Although many candidates noted the relatively small aperture of this telescope and its low magnification (17.5x), marks were awarded for commenting on its suitability for observing numbers of sunspots. Given that the Sun is extremely bright and covers a relatively large angle of view, a small aperture and moderate magnification (and hence wide angle of view), were not a significant disadvantage.

A surprisingly small proportion of candidates commented on the safety features of this equipment, such as the solar filter and use of a digital camera, rather than the human eye. The safety of the observer should be the first concern in any solar observation.

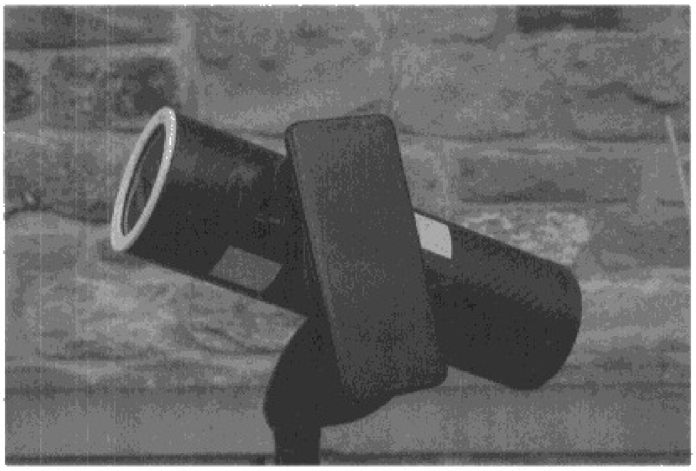


Figure 15

Details of her telescope are shown in Table 4.

Aperture	76 mm
Focal length of objective mirror	350 mm
Focal length of eyepiece lens	20 mm

Table 4

(a) Analyse the information in Figure 15 and Table 4 in order to comment on the suitability of her observing equipment.

(3)

The telescope has a very small aperture of 76mm meaning only a small amount of light will be collected resulting in a low resolution image making it hard to detect sunspots due to fuzziness.

Additionally, the telescope only has a magnification of 17.5x so the sun will appear very small making it hard to observe sunspots. It is good she is using a solar filter as it allows safe observations of the sun.

Examiner Comments

This candidate's response is just sufficient for the award of three marks, although there are several ways in which it could be improved, to align more closely with the requirements of the question.

Firstly, the candidate makes the point that an aperture of 76mm is relatively small and will not let in much light. They then link this, correctly, to resolution. However, although this is a valid point, it could be made much more strongly if it were linked to the enormous brightness of the Sun, concluding that it is not a disadvantage in this application.

Their comments about this reducing the theoretical resolution of the telescope are technically correct but would not have much effect in this case. A sunspot group will be well above this resolution limit and should not suffer from 'fuzziness'.

Secondly, they have used the data in Table 4 correctly, to calculate the magnification of the telescope – 17.5x. They could have improved this point by going on to say that the low magnification creates a relatively wide angle of view, which is ideal for viewing the entire solar disc in a single image.

Thirdly, they have mentioned the safety benefits of using a phone camera to record the images instead of viewing them directly through the eyepiece. They could have gone on to say that the permanent image recorded by the phone camera will make the counting of sunspots much easier to perform accurately.

Total: 3 Marks

Question 9 (b)

It was pleasing to see almost all candidates providing a Level 2 or higher response for this question.

The majority showed a good balance between positive features of the observations and areas for improvement. The higher-quality responses to this question showed a clear evaluation of the strengths and weaknesses of these observations, rather than just a list of each. They also made greater use of specific astronomical terms throughout.

Her observations are summarised in Table 5.

Date	Number of sunspots
1st January 2014	52
2nd July 2014	42
3rd January 2015	33
1st July 2015	25
1st January 2016	18
1st July 2016	10

Table 5

(b) Evaluate ways to improve her observations in order to obtain a more accurate estimate of the length of the Solar Cycle.

(6)

- Record sunspots on a weekly basis to obtain more accurate (up to date) data.
- Observe the Sun at the start of its ~~solar~~ solar cycle / when sunspots are lowest in number.
- Observe over a period of 11 years minimum to obtain full readings for the sunspots
- Record the rotational period of the sun at the tropics by ~~recording~~ recording the changing position of sunspots in order to estimate no. of sunspots on the far side of the Sun

ResultsPlus
Examiner Comments

This clearly-expressed response (Level 2) contains only a few points from the list provided in the Indicative Content and thus gains 3 marks.

Total: 3 Marks

Question 9 (c)

Many candidates misinterpreted this question as asking for a description of the apparent changing position of sunspot groups due to the Sun's rotation. The question required candidates to describe how the appearance of a sunspot group (not its position) changed as the group evolved and eventually dispersed.

Along with many other questions in the GCSE Astronomy examination, it was essential to read the question fully and identify the exact points that it required. Writing about other points inevitably gains no marks.

(c) While completing her observations, she noticed that groups of sunspots change their appearance.

Describe how a group of sunspots changes its appearance over a period of one month.

(2)

They move positions and fade as the Sun rotates and they move across the face of the Sun

ResultsPlus
Examiner Comments

Although this candidate broadly identifies one feature of the evolution of sunspot groups ('fade'), their answer is still primarily focussed on how the group will appear to move across the solar disc, due to the rotation of the Sun.

Total: 1 Mark

ResultsPlus
Examiner Tip

Read the question!

Question 10 (a)(i)

There were some excellent explanations provided for this question, showing a clear understanding of the logarithmic nature of the magnitude scale. Many candidates strengthened their answers by calculating 2.5^{26} and showing that it was close to 20 billion.

A few candidates misinterpreted this question as asking why the Sun appears so much brighter than Canopus, emphasising the need to read all questions very carefully before answering.

10 (a) The Sun has an apparent magnitude of approximately −27

The bright star Canopus has an apparent magnitude of approximately −1

The Sun appears approximately 20 billion times brighter than Canopus.

(i) Explain why the apparent magnitude of the Sun is only 27 times that of Canopus, even though it appears 20 billion times brighter.

(2)

$-27 - -1 = -26$ $\cancel{26 \times 2.5}$ 2.5^{26}

Each step of magnitude is 2.5× dimer/brighter. There are 26 steps between the sunan Canopus showing that the sun is 2.5^{26} times brighter

ResultsPlus
Examiner Comments

This response shows a clear understanding of the fact that each step on the magnitude scale increases brightness by a factor of approximately 2.5 times. Consequently, an increase of 26 magnitudes represents a very large increase in brightness.

Total: 2 Marks

Question 10 (a)(ii)

Although a large number of candidates understood how to attempt this calculation, a significant number did not gain full marks on this question because they did not take account of its command word 'Show…'.

As the Mark Scheme indicates, the marks on this question were for showing how an answer of around 4.5 is achieved. Some marks could be obtained by substituting numbers from the question into the distance modulus equation. However, this was not entirely straightforward because the distance (d) between the Earth and the Sun is given in kilometres on the Formulae and Data Sheet but needs to be in parsecs for this equation.

The third mark in this question was thus for converting d into parse, although many candidates did not make this important calculation explicit in their answers.

Candidates who completed the calculation correctly using the data in the question obtained a value of around 4.57 for the absolute magnitude of the Sun.

Responses to this question illustrated the importance of making each stage of a calculation clear, particularly in 'Show…' questions where all marks are for the working leading up to the final answer.

(ii) Show that the Sun has an absolute magnitude of approximately +4.5

Assume that the Sun has an apparent magnitude of −27

Use information from the Formulae and Data Sheet.

Use the equation:

$$M = m + 5 - 5 \log d$$

(4)

$M = ?$ $m = -27.$ $d = 1AU = \cancel{ks} = 4.83 \times 10^{-6}$ pc

$M = (-27) + 5 - (5 \times \log(4.83 \times 10^{-6}))$

$= -27 + 5 - (-26.5)$

$= -27 + 5 + 26.5$

$M = +4.5$

ResultsPlus
Examiner Comments

This candidate recognises the command word in this question – 'Show...'.

They make a conscious effort to 'show' clearly what they are doing at each stage of the calculation, rather than simply presenting a jumble of numbers with the intended answer underlined at the bottom.

They start their answer by writing out the values they will be inserting for each variable. This is an excellent strategy, used by only a minority of candidates.

The various stages of the calculation are sensibly placed on separate lines, leading clearly to their final answer at the bottom.

The sub-calculation of the distance in parsecs is integrated by means of brackets.

The only possible improvement would be to include the actual value that results from their calculation (about 4.57) so that it is clear that they have not simply copied '4.5' from the question.

Total: 4 Marks

Question 10 (a)(iii)

Almost all candidates appreciated that the Sun has a very bright apparent magnitude as a consequence of its very small distance from the Earth in interstellar terms and thus gained the first mark.

A pleasing proportion of candidates also explained that the Sun's apparent magnitude is brighter than its absolute magnitude because it is closer than 10pc – the distance from which absolute magnitude is calculated.

(iii) Explain why the Sun's apparent magnitude is so much brighter than its absolute magnitude.

(2)

Because it is so close to Earth so we recieve alot of light.

ResultsPlus
Examiner Comments

This response establishes the closeness of the Sun to Earth as the cause, and thus gains one mark.

The significance of the distance of 10pc in the relative sizes of the absolute and apparent magnitudes is not mentioned.

Total: 1 Mark

Question 10 (b)(i)

Most candidates understood that Star A must be further from the Earth if it appears the same brightness as Star B, but is actually three magnitudes brighter.

Question 10 (b)(ii)

This question helped to differentiate candidates in relation to their understanding of how stellar magnitude is linked to brightness, and then to distance via the inverse square law.

Although many candidates were able to complete some of the initial steps in its solution, only a very few were able to work through to the correct answer.

After realising that a magnitude difference of three equates to a brightness difference of about sixteen times, the next step was to understand that this could be achieved by placing Star A four times further away than Star B.

If Star A is 60pc from the Earth, then this would require Star B to be at 60/4 = 15pc from Earth.

As is always the case with extended calculation questions like this, a number of marks were available for candidates who made clear each of the stages in working out their answer.

This candidate's answer is also an excellent example of showing full and clear working.

If this candidate had arrived at an incorrect final answer, they would still have been able to gain a number of marks for working, because each stage is clearly presented and thus easily accessible to the examiner.

(ii) Star A is 60 pc from the Earth.

Calculate the distance of Star B from the Earth.

Give your answer in parsecs (pc).

(3)

$2.5^3 \simeq 16$ times brighter

luminosity $\propto \frac{1}{d^2}$

$d^2 \propto \frac{1}{\text{luminosity}}$

$d \propto \sqrt{\frac{1}{\text{luminosity}}}$ = 0.25 times further

$60 \times 0.25 = 15$ pc

Distance of Star B = 15 pc

ResultsPlus
Examiner Comments

This candidate reaches the correct answer for this calculation (15pc) and thus gains full marks.

As their working shows, they deduce that a sixteen times difference in brightness, which implies a four times difference in distance, makes Star B four times closer than Star A.

Total: 3 Marks

ResultsPlus
Examiner Tip

Always show your working. You will usually receive some marks.

Paper Summary

Summary

Based on this year's examination, the following points have been identified as areas where future candidates could strengthen their performance in this qualification:

- ‘Explain’ means **why** something happens, not ‘what'
- ‘Compare’ requires both sides of the argument
- ‘Evaluate’ means arrive at a judgment
- ’Show’ – needs each step of reasoning in the working
- Label diagrams fully
- Bring a suitable calculator
- Know how to operate the calculator
- Show your working in a structured way
- Round your answer to a sensible number of significant figures
- Use given data when required to do so

Grade boundaries

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