

Formulae and Data Sheet

Formulae

| | |
|--|---|
| Equation of Time = Apparent Solar Time (AST) – Mean Solar Time (MST) | |
| Kepler's 3rd law: | $\frac{T^2}{r^3} = \text{a constant}$ |
| Magnification of telescope: | magnification = $\frac{f_o}{f_e}$ |
| Distance modulus formula: | $M = m + 5 - 5 \log d$ |
| Redshift formula: | $\frac{\lambda - \lambda_0}{\lambda_0} = \frac{v}{c}$ |
| Hubble's law: | $v = H_0 d$ |

Data

| | |
|----------------------------------|-------------------------------------|
| Mass of Earth | 6.0×10^{24} kg |
| Mean diameter of Earth | 13 000 km |
| Mean diameter of Moon | 3500 km |
| Mean diameter of Sun | 1.4×10^6 km |
| One Astronomical Unit (AU) | 1.5×10^8 km |
| Mean Earth to Moon distance | 380 000 km |
| One light year (l.y.) | 9.5×10^{12} km |
| One parsec (pc) | 3.1×10^{13} km = 3.26 l.y. |
| Sidereal day of Earth | 23 h 56 min |
| Synodic day of Earth | 24 h 00 min |
| Temperature of solar photosphere | 5800 K |
| Hubble Constant | 68 km/s/Mpc |
| Speed of light in vacuum | 3.0×10^8 m/s |

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| Name | Type of body | Mean distance from Sun/AU | Sidereal period/Earth year | Mean temperature /°C | Diameter /1000 km | Mass/Earth mass | Ring system | Moons |
|---------|--------------|---------------------------|----------------------------|----------------------|-------------------|----------------------|-------------|--|
| Mercury | planet | 0.38 | 0.24 | 170 | 4.9 | 0.055 | no | none |
| Venus | planet | 0.72 | 0.62 | 470 | 12.1 | 0.82 | no | none |
| Earth | planet | 1.0 | 1.0 | 15 | 12.8 | 1.00 | no | 1: the Moon |
| Mars | planet | 1.5 | 1.9 | -50 | 6.9 | 0.11 | no | 2 small moons: Deimos and Phobos |
| Ceres | dwarf planet | 2.8 | 4.6 | -105 | 0.95 | 1.5×10^{-4} | no | none |
| Jupiter | planet | 5.2 | 11.9 | -150 | 143 | 318 | yes | 4 major moons: Ganymede, Callisto, Europa, Io >60 others |
| Saturn | planet | 9.5 | 29.5 | -180 | 121 | 95 | yes | 5 major moons: including Titan, Iapetus >55 others |
| Uranus | planet | 19.1 | 84.0 | -210 | 51 | 15 | yes | 5 major moons: including Titania, Oberon >20 others |
| Neptune | planet | 30.0 | 165 | -220 | 50 | 17 | yes | 1 major moon: Triton >12 others |
| Pluto | dwarf planet | 39.5 | 248 | -230 | 2.4 | 2.2×10^{-3} | no | 1 major moon: Charon >4 other moons |
| Haumea | dwarf planet | 43.1 | 283 | -241 | 1.4 | 6.7×10^{-4} | no | 2 |
| Eris | dwarf planet | 67.8 | 557 | -230 | 2.3 | 2.8×10^{-3} | no | at least 1 |

Answer ALL questions. Write your answers in the spaces provided.

Some questions must be answered with a cross in a box . If you change your mind about an answer, put a line through the box and then mark your new answer with a cross .

- 1 (a) A student makes a sketch of the surface of the Moon, as shown in Figure 1.

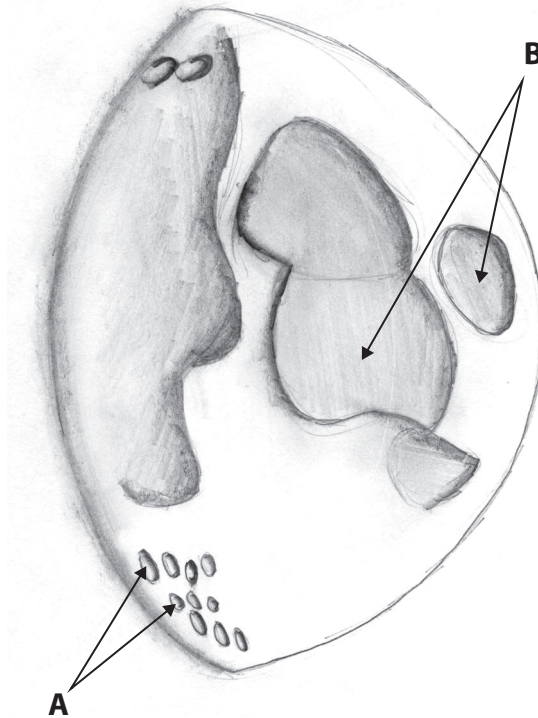


Figure 1

- (i) Identify which phase of the Moon is shown in Figure 1.

(1)

- A crescent
- B full
- C gibbous
- D new

- (ii) Identify the small circular features labelled A in Figure 1.

(1)

- A craters
- B mare
- C mountains
- D terrae



(iii) Identify the large dark areas labelled **B** in Figure 1.

(1)

- A** craters
- B** mare
- C** mountains
- D** terrae

(b) An astronomer writes a short description of two objects in the night sky.

(i) A short, bright streak of light that is visible for less than a second.

State the name of the object most likely to cause this streak of light.

(1)

(ii) A point of coloured light that moves across the sky in a few minutes, flashing in a regular way.

State the name of the object most likely to cause this point of light.

(1)

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(c) In 1577, a very bright comet was visible from Earth.

The Danish astronomer Tycho Brahe described the comet.

He wrote that the comet's tail covered almost a quarter of the sky and that the comet was much brighter than a full Moon.

Draw on Figure 2 a sketch of a bright comet, like the comet seen in 1577.

(3)



Figure 2

(Total for Question 1 = 8 marks)



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2 (a) Which of the following is the largest?

(1)

- A a galaxy
- B a moon
- C a nebula
- D a planet

(b) Which of these stars is **not** part of the Summer Triangle asterism?

(1)

- A Altair
- B Arcturus
- C Deneb
- D Vega

(c) (i) Which of the following would **halve** the gravitational force between the Earth and the Moon?

(1)

- A doubling the distance between the Earth and the Moon
- B doubling the mass of the Earth
- C halving the mass of the Moon
- D halving the distance between the Earth and the Moon

(ii) Which of the following would **quadruple** the gravitational force between the Sun and Jupiter?

(1)

- A doubling the distance between the Sun and Jupiter
- B doubling the mass of the Sun
- C halving the mass of Jupiter
- D halving the distance between the Sun and Jupiter



(d) A star has an hour angle of zero.

Which of the following gives the position of the star?

(1)

- A** on the observer's equator
- B** on the observer's horizon
- C** on the observer's meridian
- D** on the observer's zenith

(e) (i) State the name of the planet that has the shortest sidereal period.

(1)

(ii) State the name of the planet that comes closest to the Earth.

(1)

(f) Alice is in the UTC+3 time zone and Bob is in the UTC-4 time zone.

Clocks in Alice's location show 6pm.

State the time shown by clocks in Bob's location at this time.

(1)

(Total for Question 2 = 8 marks)



3 (a) (i) Draw a sketch of the asterism known as 'The Plough'.

(2)

(ii) Draw an arrow on your sketch to show the direction of the bright star Polaris.

(1)

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(b) (i) Draw a sketch of the seven brightest stars in the constellation of Orion.

(2)

(ii) Label the position of the bright star Betelgeuse on your sketch.

Use the label **B**.

(1)

(iii) Label the position of the Orion Nebula on your sketch.

Use the label **N**.

(1)



(iv) The stars in the constellation of Orion have been observed by people living at a wide range of latitudes.

The Inuit people observed the stars of Orion from a latitude of over 70°N .

People in South America observed the stars of Orion from a latitude of 55°S .

Explain why the stars in Orion are visible over such a wide range of latitudes.

You may include a clearly labelled diagram in your answer.

(2)

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(Total for Question 3 = 9 marks)



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- 4 (a) Table 1 shows the rising and setting times for the Sun and the Moon on four different dates.

| Date | Sunrise Time | Sunset Time | Moonrise Time | Moonsset Time |
|------|--------------|-------------|---------------|---------------|
| A | 04:50 | 21:30 | 10:51 | 03:30 |
| B | 06:25 | 18:32 | 18:27 | 06:21 |
| C | 07:39 | 16:45 | 07:38 | 16:44 |
| D | 08:10 | 15:51 | 08:41 | 16:21 |

Table 1

- (i) Identify the date from Table 1 (A, B, C or D) when a full Moon would be most likely.

(1)

Date:

- (ii) Identify the date from Table 1 (A, B, C or D) when a crescent Moon would be most likely.

(1)

Date:

- (iii) Identify the date from Table 1 (A, B, C or D) when a solar eclipse would be most likely.

(1)

Date:



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(b) Explain why there is **not** a solar and a lunar eclipse every month.

You may include a clearly labelled diagram in your answer.

(3)

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(c) Eid al-Fitr is a festival in the Islamic calendar.

The passage below explains how the date of Eid al-Fitr is found each year.

"The festival of Eid al-Fitr falls on the first day of the month of Shawwal. On the last day of the previous month, astronomers look carefully in the sky for the first sight of the start of the crescent Moon phase. Once this very thin crescent Moon has been seen, the New Moon phase is over and the month of Shawwal begins, with the festival of Eid al-Fitr."

(i) An astronomy student suggests:

"Why not start each month with a full Moon – it is much easier to see in the sky."

Explain **one** astronomical advantage of starting each month with the first sight of the crescent Moon instead of the full Moon.

(3)

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(ii) Table 2 shows the dates of Eid al-Fitr in recent years.

| Year | Date of Eid al-Fitr |
|------|---------------------|
| 2021 | 12th May |
| 2022 | 1st May |
| 2023 | 20th April |
| 2024 | 9th April |

Table 2

Explain why Eid al-Fitr is on a different date each year.

(2)

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(Total for Question 4 = 11 marks)



5 (a) Explain what is meant by the 'Equation of Time'.

(2)

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(b) Table 3 contains some data about the length of daylight during December.

| Date | Sunrise Time | Sunset Time | Length of Daylight (h:min) | Equation of Time (min:s) |
|----------|--------------|-------------|----------------------------|--------------------------|
| 19th Dec | 08:23 | 15:46 | 7:23 | 3:02 |
| 20th Dec | 08:24 | 15:47 | 7:23 | 2:32 |
| 21st Dec | 08:25 | 15:47 | 7:22 | 2:03 |
| 22nd Dec | 08:25 | 15:47 | 7:22 | 1:33 |
| 23rd Dec | 08:25 | 15:48 | 7:23 | 1:03 |
| 24th Dec | 08:25 | 15:49 | | 0:33 |
| 25th Dec | 08:25 | 15:50 | | 0:04 |

Table 3

(i) Complete Table 3 by calculating the **two** missing Length of Daylight times.

(1)



In the Earth's northern hemisphere, December 21st is the date of the winter solstice.

This date is often referred to as the 'shortest day' of the year.

- (ii) State the reason that December 21st is often referred to as the 'shortest day' of the year.

(1)

- (iii) Explain why the Sun does **not** rise at an earlier time on the days after 21st December, even though the winter solstice has passed.

You may include a clearly labelled diagram in your answer.

(3)

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P 7 8 6 9 1 A 0 1 9 4 0

(c) Figure 3 shows the Earth and the orbit of Venus around the Sun.
 Four positions in Venus's orbit have been labelled (A, B, C and D).

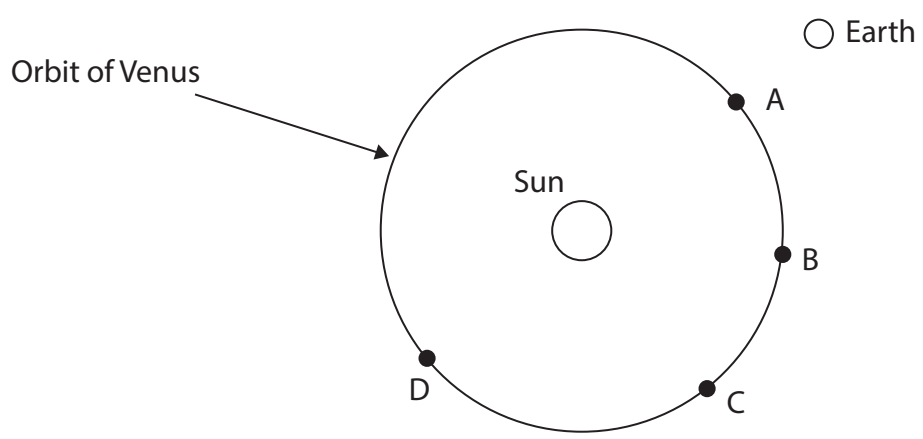


Figure 3

(i) Identify the position in Figure 3 (A, B, C or D) where Venus would be at superior conjunction for an observer on the Earth.

(1)

Position:

(ii) Identify the position in Figure 3 (A, B, C or D) where Venus could appear to transit the Sun, for an observer on the Earth.

(1)

Position:

(iii) Identify the position in Figure 3 (A, B, C or D) where Venus would be best placed for observation from the Earth.

(1)

Position:

(Total for Question 5 = 10 marks)



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6 Box Hill Tunnel is a railway tunnel in the south-west of England.

Figure 4 shows a map of the tunnel and a picture of one of its entrances.

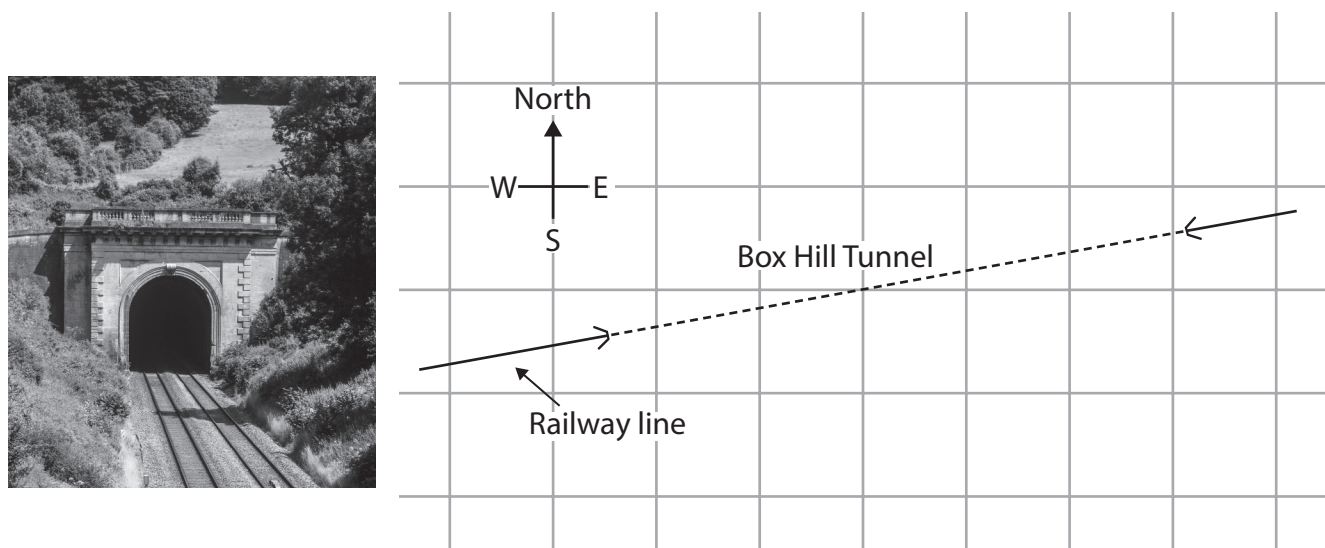


Figure 4

It has been suggested that the Sun shines directly through the tunnel on only one occasion each year – at sunrise on 9th April.

Table 4 shows the azimuth of the Sun at sunrise on some dates during April.

| Date | Azimuth of Sun at sunrise |
|------------|---------------------------|
| 2nd April | $81^{\circ}30'$ |
| 4th April | $80^{\circ}00'$ |
| 6th April | $78^{\circ}45'$ |
| 8th April | $77^{\circ}30'$ |
| 10th April | $76^{\circ}00'$ |
| 12th April | $75^{\circ}00'$ |
| 14th April | $74^{\circ}00'$ |

Table 4

(a) (i) Plot on Figure 5 a graph of the Sun's azimuth at sunrise from 2nd April to 14th April.

Use the data in Table 4.

(3)



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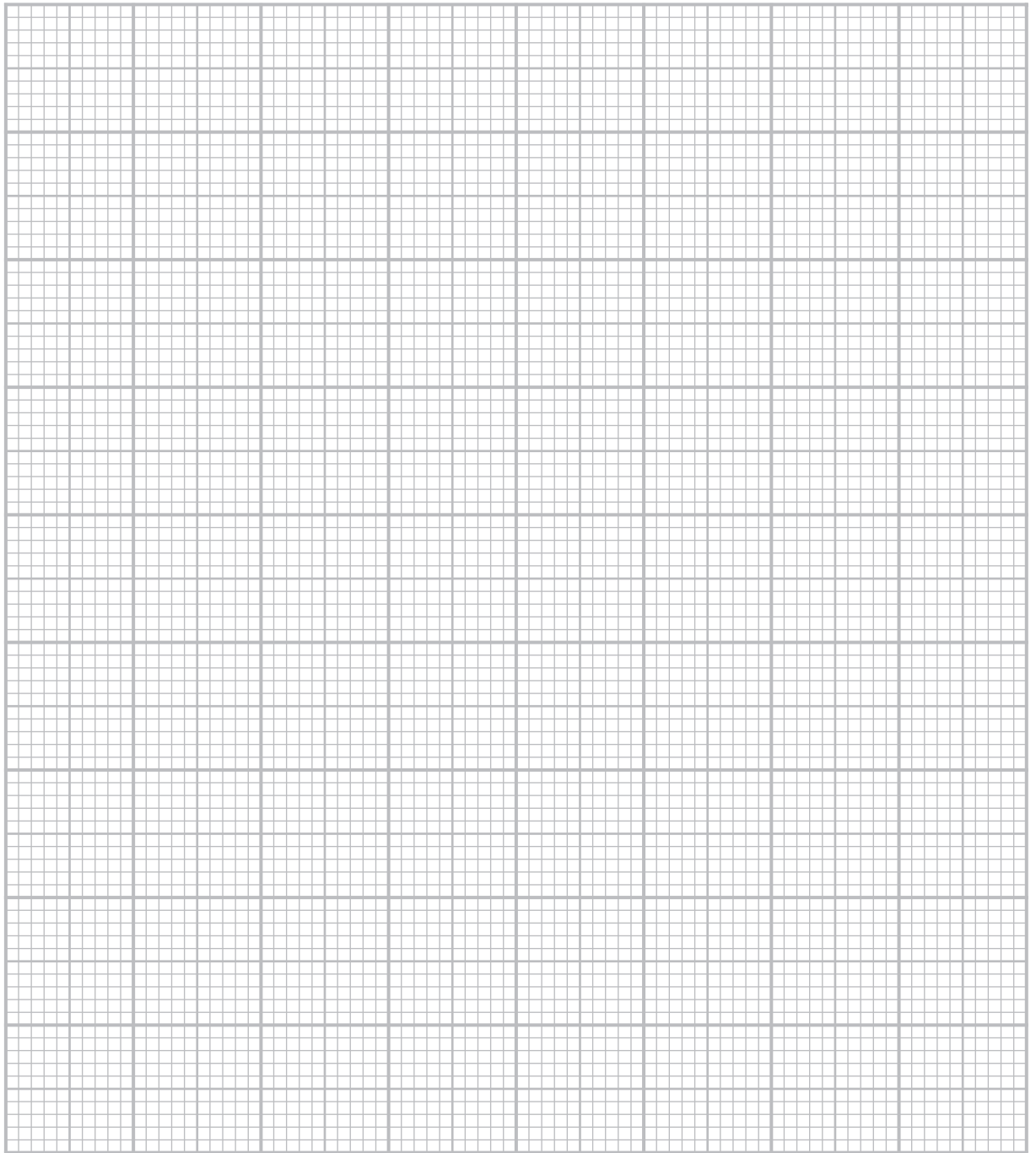


Figure 5

(ii) Estimate the azimuth of the Sun at sunrise on 9th April.

Use the information in Table 4 and Figure 5.

(1)

Azimuth =°.....'



(b) Evaluate the suggestion that the Sun shines through Box Hill Tunnel on only one occasion each year – at sunrise on 9th April.

Use information from Figure 4, Table 4 and Figure 5.

(6)

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(Total for Question 6 = 10 marks)

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7 Owen is planning to make some naked-eye observations of the Milky Way.

(a) Describe how the Milky Way appears in the night sky to a naked-eye observer. (2)

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(b) Owen uses a planisphere to help plan his observations.

Owen sets up his planisphere correctly for observations at 11 pm.

Part of his planisphere is shown in Figure 6.

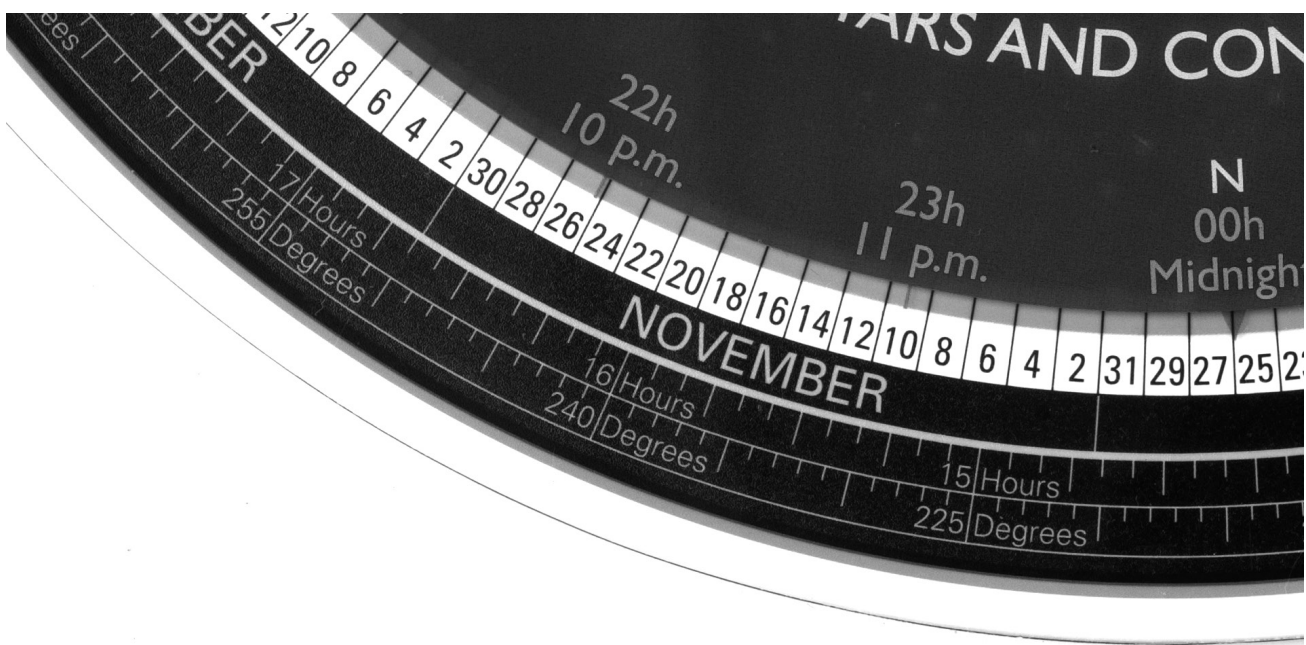


Figure 6

(i) State the date Owen is planning to make his observations. (1)

Use information from Figure 6.

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(ii) State **two** advantages of using a planisphere, rather than a star map, when planning observations.

(2)

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(c) Figure 7 shows the area near to where Owen lives.



Figure 7

Design a suitable observing programme that will allow Owen to make accurate sketches of the Milky Way.

Use information from Figure 7 to help you include suggestions for an appropriate observing site.

(6)

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Handwriting practice area with 20 horizontal dotted lines.

(Total for Question 7 = 11 marks)

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8 (a) In the third century BCE, the Greek astronomer Aristarchus made observations of a last quarter Moon.

He used these observations to calculate how many times further away from the Earth the Sun was than the Moon.

Explain how he was able to do this.

You may include a clearly labelled diagram in your answer.

(4)

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- (b) Aristarchus combined his measurement with other measurements to estimate the distance from the Earth to the Sun.

A summary of these measurements is shown in Table 5.

| Measurement | Value |
|---|----------|
| Radius of Earth | 6 300 km |
| Ratio of distance to Moon and diameter of Earth | 10 |
| Ratio of distance to Sun and distance to Moon | 19 |

Table 5

- (i) Calculate a value for the distance from the Earth to the Sun.

Use the information in Table 5.

Show each stage in your working clearly.

(3)

Distance from the Earth to the Sun = km



- (ii) Calculate the percentage error in your value for the distance from the Earth to the Sun.

Use information from the Formulae and Data Sheet.

Use the equation:

$$\text{Percentage error} = \frac{(\text{Calculated distance} - \text{true distance})}{\text{True distance}} \times 100\% \quad (2)$$

Percentage error =%

- (iii) Astronomers in ancient times were able to make very accurate observations of objects in the sky.

However, estimates of the distance from the Earth to the Sun in ancient times were very inaccurate.

Explain why these estimates were very inaccurate.

(2)

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(Total for Question 8 = 11 marks)



- 9 Figure 8 shows the weather vane at Sydney Observatory in Australia.
The photograph was taken shortly after local noon on 21st March.



Figure 8

Sydney has a latitude of 34°S .

- (a) Calculate the altitude and azimuth of the Sun at local noon in Sydney on 21st March.

(4)

Altitude =

Azimuth =



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- (b) On 21st June, the Sun reaches its highest point in the sky in Sydney at 01:53 GMT.
The Equation of Time on 21st June is +2 minutes.
Calculate the longitude of Sydney.
Give your answer to the nearest degree.

(4)

Longitude of Sydney =°

- (c) The star Canopus culminates at an altitude of $71^{\circ}18'$ when observed from Sydney.
Calculate the declination of the star Canopus.

(3)

Declination =°'

(Total for Question 9 = 11 marks)



10 (a) Objects in the sky appear to move from east to west once every day.

Which of the following is the name of this motion?

(1)

- A diurnal
- B ecliptic
- C heliocentric
- D zodiacal

(b) Observations of planets show that they appear to perform 'retrograde motion'.

Explain what is meant by the 'retrograde motion' of a planet.

You may include a clearly labelled diagram in your answer.

(2)

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(c) (i) A student comments: "The planet Mars orbits the Sun at a distance of 1.5 AU but takes a lot more than 1.5 years to complete one orbit."

Explain why Mars takes much more than 1.5 years to orbit the Sun.

(2)

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(ii) The asteroid 2530 Shipka orbits the Sun at a mean distance of 3.0 AU.

Calculate the orbital period of this asteroid.

Give your answer in years.

(3)

Orbital period = years



- (iii) An astronomer has discovered three exoplanets.
These three exoplanets all orbit the same star.

Some information about the orbits of these exoplanets is shown in Table 6.

| Exoplanet | Mean orbital radius (AU) | Orbital period (years) |
|-----------|--------------------------|------------------------|
| A | 1.5 | 0.64 |
| B | 3.0 | 1.81 |
| C | 4.5 | 3.33 |

Table 6

Calculate the mass of the star that these three exoplanets orbit.

Use information from Table 6.

Give your answer in solar masses.

(3)

Mass of star = solar masses

(Total for Question 10 = 11 marks)

TOTAL FOR PAPER = 100 MARKS



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Figure 4 – © nikonpete/Shutterstock

