AstroChallenge 2024
Theory Observation (Team A) Round

SOLUTIONS

Monday 3rd June 2024

PLEASE READ THESE INSTRUCTIONS CAREFULLY.

1. This paper consists of **20** printed pages, including this cover page.
2. Do **NOT** turn over this page until instructed to do so.
3. You have **1.5 hours** to attempt **ALL** questions in this paper.
4. The marks for each question are given in brackets in the right margin, like such: **[2]**.
5. The **alphabetical** parts (i) and (l) have been intentionally skipped, to avoid confusion with the Roman numeral (i).
6. Ensure that your school and team number are clearly on the cover of this booklet.

Section A Celestial Valentine

This section contains two (2) tasks. Task 1 requires you to draw a finder chart for use by Team B, while Task 2 requires you to use the software Stellarium to follow the instructions on the finder chart drawn by Team B. You have a maximum of 20 minutes to attempt Task 1. You will need to hand in your Task 1 by the end of 20 minutes. After which, you can attempt Task 2 whenever you wish to, throughout the rest of the duration of the paper.

Background

It is the year 2069 and humans have colonised planet Mars and established a colony base on where it used to be called "Utopia Planitia". Elon Musk, as remembered by those born in the early 21st century, is now seen as a legendary figure who inspired the entire human race on their adventure into deep space and the development of the reusable what was once called the "Big Falcon Rocket".

Samantha and Walter knew each other since young. Having a degree in astronomy and hence being selected as a critical part in the colony base maintenance team, Samantha has the privilege to work on the Mars colony base and has access to the base's telescope stock during her free time. Walter, under the influence of his partner, had become an astronomy enthusiast and owns a collection of telescopes and accessories. On the last day of 2069, the couple wanted to look at each other through their own telescopes.

Task 1 [15 marks]

Your team will be helping with Walter in guiding him in finding Mars. Walter used Aldebaran to adjust his telescope set-up and hence this is where his telescope is currently pointing at. Draw a finder chart with the appropriate instructions in helping him star-hopping to Mars.

Figure 1 on the next page shows the screenshot on the software Stellarium, that indicates the sky Walter will be looking at. You should use it as a reference when drawing your star chart. Each box on Figure 1 represents **5 degrees** on the altitude–azimuth coordinate system.

You have access to the following equipment:

- 50 mm finder (5.5° FOV; 5× magnification)
- Newtonian reflector (125 mm diameter; 600 mm focal length) on an altitude–azimuth mount
- Eyepieces: 4 mm (50°), 15 mm (58°) and 25 mm (44°)

On your finderchart, you should include the following:

- The choice of equipment and accessories that you want Walter to use. You may ask him to switch between the different accessories that is available to him.
- Calculate/state the field of view for the combination of equipment and accessories you wish Walter to use.
- Brief explanation on how Walter can be sure that he has found Mars (end point). You may use any sketch/labelling in aiding your explanation.
- Any instructions that Walter should follow. It is advisable to use sketches extensively in giving the instructions.
- You are advised against instructing Walter to slew to his end target in one step only. Some information about the sky between his starting and ending points would be required.

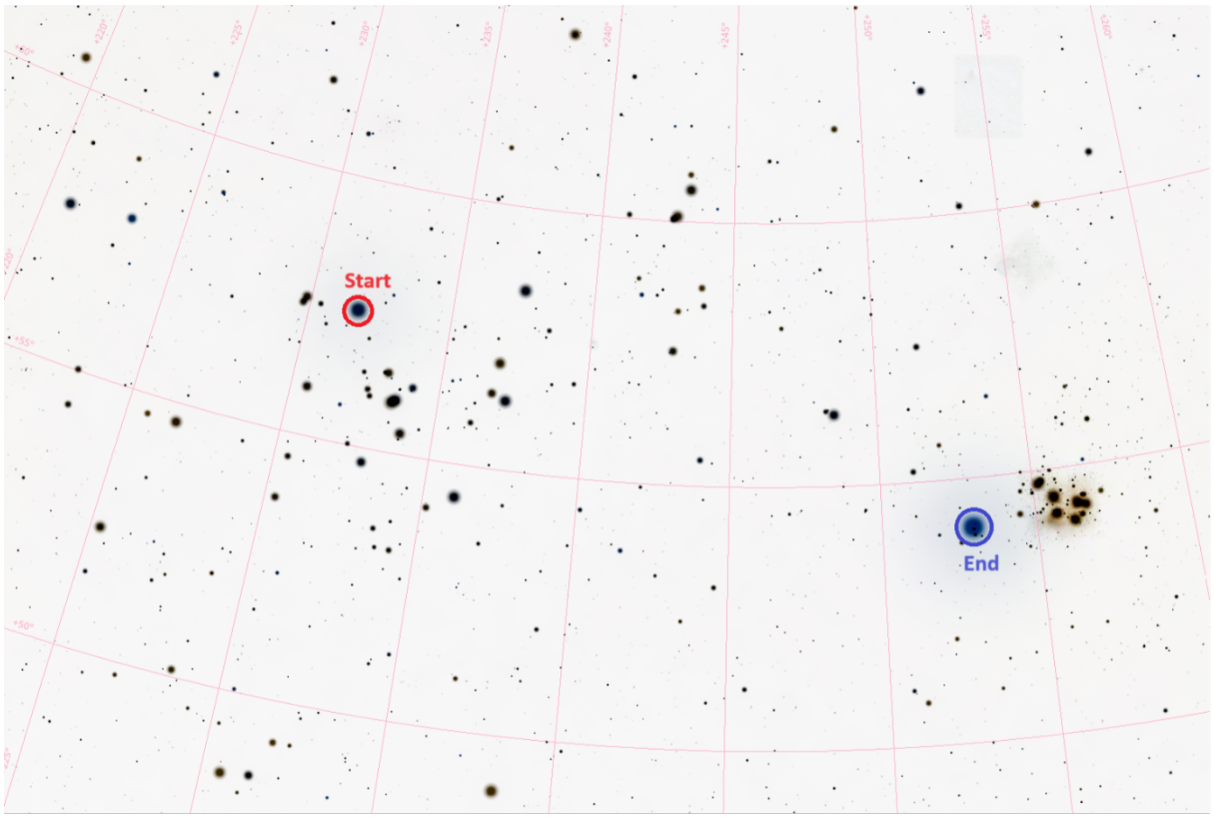


Figure 1: Walter's sky.

Task 2 [5 marks]

Your team will now use the software Stellarium, that is positioned at exactly where Samantha is, to find Walter using the instruction sent to you from the other team.

You have access to the following equipment:

- 50 mm finder (5.5° FOV; 5× magnification)
- Newtonian reflector (125 mm diameter; 600 mm focal length) on an altitude–azimuth mount
- Eyepieces: 4 mm (50°), 15 mm (58°) and 25 mm (44°)

You have 10 minutes to attempt this task. You may only use the arrow keys to slew the telescope and request to change the accessories you are using. You may ask the facilitator to reset your telescope to the starting position a maximum of two (2) times during the 10 minutes. The time it takes for facilitator to do so would be included in the 10 minutes you have (i.e., time would not be paused).

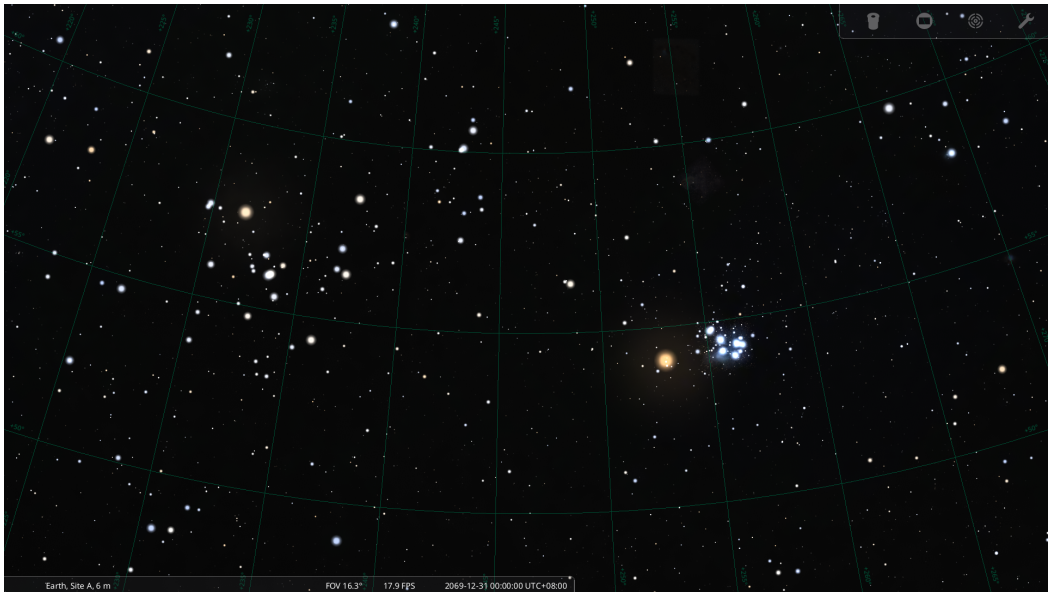
A successful attempt includes you identifying the correct end point to the invigilator. You will only be allowed **one** chance to do so.

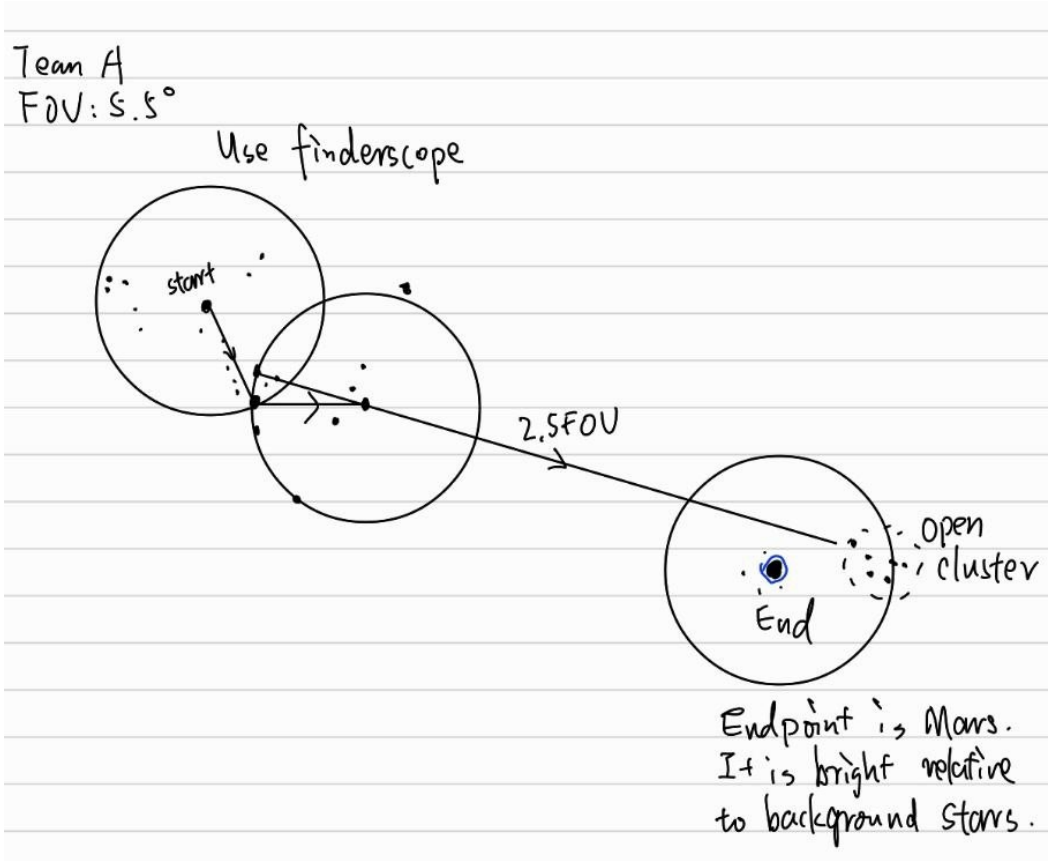
Partial credit will be awarded if you have pointed out the wrong end point, but the actual end point can be seen in the final FOV after facilitator centres the FOV on the object you have pointed out, **without** changing the equipment configuration you last used.

You are strongly advised to point out an endpoint.

Solution:

Time: 2069-12-31 0000hrs UTC+8
Location: Earth, 39°55'43.00"N, 116°23'20.00"E
Start: Aldebaran
End: Mars (near M45)





Finderchart (drawing) marking scheme:

Requirement	Mark
Indication of the choice of equipment and accessories (eg. “use finder”)	2
The correct indication of field of view for the choice of equipment. -Calculation steps are not necessary as long as the result is correct, with rounding error of ±1 unit at the last significant figure acceptable. -If the instruction involves switching equipment, the true FOV of all combination must be correctly calculated. -Proportional deduction if any number of combination is missing/incorrect. Eg if three combinations are used but only two calculated are correct, then only 66.7% of marks are awarded. -If calculation method is indicated and is correct, but final answer wrong, then half of the marks worth of that calculation is given. Eg if three combinations are used but only one combination is calculated, with the steps being correct and final answer wrong, then in total, only 16.7% of the marks are awarded. -Round down to the nearest 0.5 marks	3
Brief explanation on how the endpoint should be found. -A simple labelling of end point object with the sketch of other stars around would award full credit. -Alternatively, any length of description that achieve the same or similar effect to the point above would suffice too. -Stating the name of the object alone only award 1 mark.	2
Sketch and/or accurate description of starting FOV that allows the marker to know which way to slew the telescope next.	2
Indication of the rough distance that the marker would be required to move for each step. -This can be done having common stars in adjacent FOVs if they are close enough -This can also be done by having numbers (eg. 2.5 FOV) with an acceptable uncertainty of ±1 FOV -This can also be done by indicating the angular distance that the telescope should slew over with an acceptable uncertainty of +5 degrees -Any other way deemed satisfactory will also credit marks **NOTE:** *Any one way of above would be sufficient for each step. *This leniency is purely for the purpose of marking the drawing. It would be very hard for the other team to find using a highly uncertain indication. *ecf is awarded for wrong FOV, as long as the measurement is consistent *Marks will be deducted accordingly in a proportional way if some of the steps are deemed not clear. *Round down to the nearest 0.5 marks.	2
Sketch and/or accurate description of intermediate FOVs/stars or objects (if any) that the marker to know which way to slew the telescope next. **NOTE:** *Proportional marking if there are multiple intermediate steps required and some are deemed not clear. *If there are no intermediate step at all, information along the way of slewing must be presented and will be marked.	4

Finderchart (finding) marking scheme:

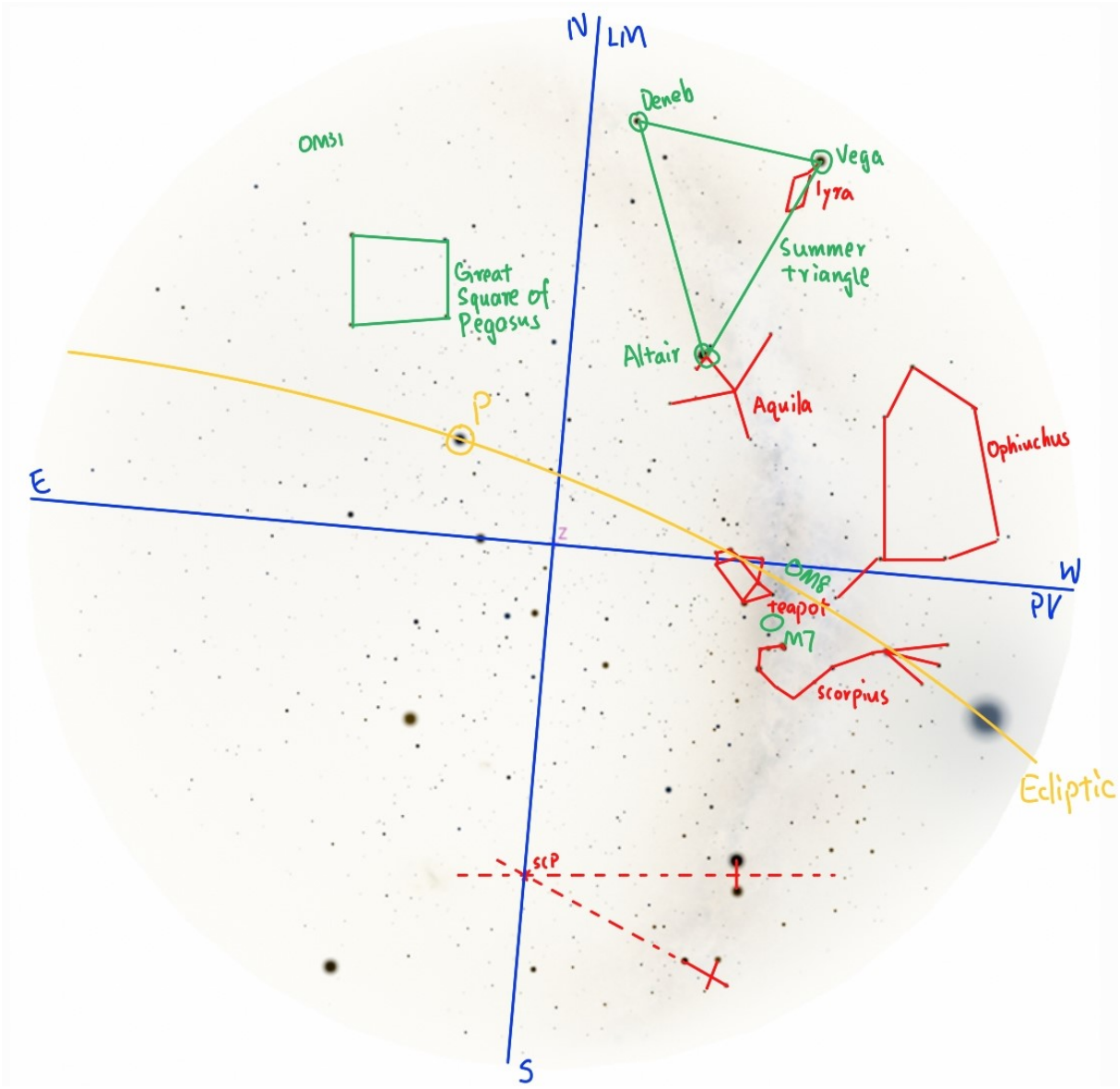
Description of achievement	Total marks awarded
Successfully found and indicated the correct end point	5
Participants indicated the wrong end point, but after centring the FOV (without changing the equipment configuration from what the participants were last using), on the indicated end point, the correct end point is within the FOV	3
Otherwise	0

Section B The Night Sky

You and your friends are on an overseas stargazing trip to Perth, Australia jointly organised by NUSAS and NTUAS. On the first night, the observation head of both clubs decided to conduct a night sky talk and jointly decided to quiz the participants on their knowledge on stargazing.

As ardent astronomers, you and your friends were determined to answer all the questions that they would quiz.

This is a stereographic projection of the sky on the night of the trip. The zenith point is marked with a pink cross and labelled for you as Z. Answer the questions in the space provided, or if so instructed, on the *star chart* on this page.



Hello everyone, welcome to the countryside of Perth, Australia! As you can see, the night sky here at the countryside is much clearer than in Singapore thanks to a lower level of light pollution.

The first thing we astronomers always need to do is to find the cardinal directions. We can find the south celestial pole in this case by drawing two particular lines.

Does anyone in the crowd know how to do it?

(a) Using this information or otherwise, on the star chart, mark out the south celestial pole with a cross (×) and label it SCP. Clearly indicate your methods of locating it. [2]

Solution:

Answer on the starchart as indicated.
Connecting Gacrux and Acrux, extending the line. [0.5]
Connecting Rigil Kentaurus and Hadar, constructing perpendicular bisector. [0.5]
Label the intersection as SCP. [1]

Next, we would need to be able to find the local meridian and prime vertical. Would anyone like to give it a try?

(b) On the star chart, trace out and the local meridian and prime vertical, labelling them LM and PV respectively. [1]

Solution:

Answer on the starchart as indicated.
LM: straight line passing through both Zenith and SCP. [0.5]
PV: straight line passing through zenith and perpendicular to LM. [0.5]

Let's see... what can we say about the cardinal directions?

(c) Label the cardinal directions on the star chart. [1]

Solution:

Answer on the starchart as indicated. [1]
If North or South wrong, 0 marks would be awarded.
If North and South are correct AND East and West are swapped, 0.5 marks would be awarded.
Allow ecf: if SCP is constructed wrongly.

As you can see, the Moon is **A** *just above the* **B** *horizon. The time now is* 9.00 pm *local time, and since the Moon is at the* **B** *horizon, the phase of the Moon is* **C** .

You missed the important information that the club observation head presented. However, you were determined to figure them out yourself.

(d) Circle the most appropriate answer for **A** and **B** . [2]

For **C** , fill in the blank and draw a diagram below to explain your answer. [2]

A: rising/setting

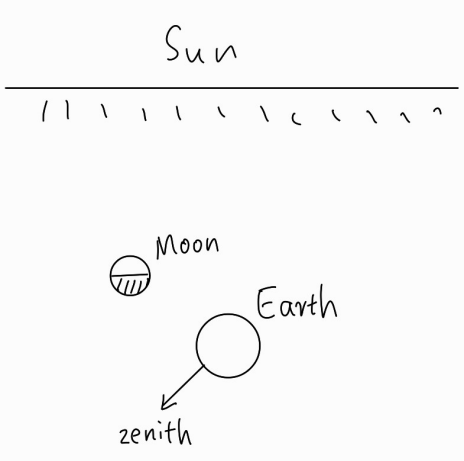
B: eastern/western

C:

Solution:

A: setting [1]
B: western [1]
C: Waxing Cresent (first half not accepted) [1]

Diagram:



For A and B:
-No ecf. Mark would be awarded if and only if the correct answer is circled.

For diagram:
-Identifying the relative direction of zenith correctly with respect to the sun, given that the time is 2100. [0.5]
-Identifying the relative direction of the sun, the Earth and the moon correctly. [0.5]
-It is not necessary to shade the dark side of the moon if the moon phase for C is correct.

If both part A and B are wrong,
-Ecf if C is Waning Gibbous.
-Ecf if the diagram shows Waning Gibbous correctly.
-No ecf otherwise, even if C and the diagram may or may not be consistent.
-No ecf even if C and diagram correctly shows Waxing crescent.

If either part A or B is wrong,
-C is expected to be Waxing Cresent. Diagram is expected to show waxing crescent correctly.
-No ecf otherwise, even if C and the diagram may or may not be consistent.

Else,
-If the diagram is wrong but moon phase for C is consistent with the diagram, ecf for C, provided that the dark side of the moon is shaded, and shaded correctly according to the relative position.
-If the moon phase for C is said to be Waxing Cresent but the diagram is wrong, mark for C would be awarded but not for the diagram.
-If the diagram is correct in showing waxing crescent, and if the dark side of the moon is shaded, but the answer for C is wrong, then mark is awarded for the diagram but not for C.
-Otherwise, no mark awarded for either C nor diagram.

You can visibly see the Milky Way tonight! The brightest part of the Milky Way occurs near the constellation Sagittarius, part of which forms the teapot asterism.

(e) Where is the teapot? Trace out and label it T on the star chart. [1]

Solution:

Answer on the starchart as indicated. [1]
No partial credit.

This direction in the sky is towards the centre of the Milky Way, and hence we are able to see many deep sky objects (DSOs). DSOs are objects that are not individual stars or Solar System objects. There are mainly three broad types of DSOs, namely ***star clusters****,* ***nebulae*** *and* ***galaxies****.*

(f) Label and circle one of each type of DSO on the star chart. [3]

Solution:

Answer on the starchart.
Correct location and name of a star cluster. [1]
Correct location and name of a nebula. [1]
Correct location and name of a galaxy. [1]

AC rule on DSO apply: it must either have a common name, or is from the Messier or Caldwell catalogue.
Accept Milky Way as a galaxy.
Accept Supernova Remnant and Planetary Nebula as Nebulae.
Do not accept black hole.

Star clusters are also classified into globular and open clusters, while nebulae are classified as diffuse nebulae, planetary nebulae, or supernova remnants. Both supernova remnants and planetary nebulae are the result of a star's death. The reason why some stars end their lives as supernova remnants, others as planetary nebulae, and some even as black holes is due to differences in their **D**.

(g) Oh no, you missed the important information again! What is **D** supposed to be? [1]

D: .....

Solution:

D: Mass [1]

Constellations are areas on the celestial sphere in which a group of visible stars forms a perceived pattern or outline, typically with mythological association. The International Astronomical Union (IAU) recognises a total of **E** *constellations, together covering the entire celestial sphere.*

(h) **E** is the total number of IAU recognised constellations. What is **E**? [1]

E: .....

Solution:

E: 88 [1]

Half credit for within ±5, ie, between 83 and 93 (inclusive).

There are many constellations visible in the night sky tonight!

(j) On the star chart, trace out and label at least three other complete constellations. [3]

Note. *Marks will not be awarded for tracing and labelling of Sagittarius, Crux or Ophiuchus. Marks will only be awarded for the correct tracing and labelling of any other constellations.*

Solution:

Accept any 3 other complete constellations that are not Ophiuchus, Sagittarius, or Crux. [3]

Mark would only be awarded if both the constellation tracing and the name is correct.

Asterisms are observed patterns or groups of stars in the sky. It is a more general concept than the constellations formally recognised by the IAU. There are a few other prominent asterisms in the night sky tonight, namely the summer triangle and the great square of Pegasus. Does anyone know where they are?

(k) On the star chart, trace out the great square of Pegasus and the summer triangle and label them GS and ST respectively. [2]

Name and label the stars that form the summer triangle as well. [1.5]

Solution:

Answer on the starchart as indicated.
Correct tracing and labelling of great square of Pegasus. [1]
Correct tracing and labelling of summer triangle. [1]
Correct identification and labelling of Altair. [0.5]
Correct identification and labelling of Deneb. [0.5]
Correct identification and labelling of Vega. [0.5]

Apart from the Moon, there is another Solar System object in the sky tonight! Would anyone like to point it out?

(m) Circle this other Solar System object out on the star chart and label it P. [1]

Note. *Marks will not be awarded for labelling the Earth.*

Solution:

Answer on the starchart as indicated. [1]
The object is Saturn. Would not be penalised if participant label it as Saturn. 0.5 marks would be deducted if the participant label it anything other than "Saturn" or "P".

The ecliptic is the apparent path of the Sun on the celestial sphere. We can therefore estimate the rough direction of the ecliptic. Would anyone give it a shot?

(n) Assuming that both the Saturn and the Moon are very near the ecliptic today, on the star chart, sketch out and label the ecliptic. [1]

Solution:

Answer on the starchart.
It is meant to be a sketch. However, a few points must be satisfied:
-The ecliptic should be a curve, resembling the shape of a great circle in stereographic projection. [0.5]
-The two ends of the ecliptic, when connected by a straight line, should pass near the zenith (ideally through zenith). [0.25]
-The ecliptic curve should be near both Saturn and the Moon. [0.25]
-The ecliptic should not cut any constellation that is obviously not a zodiac constellation (if the constellation is not directly next to a zodiac constellation or Ophiuchus). 0.25 marks would be penalised if it is the case.

NOTE:
-Lowest possible mark is 0. If none of the first three points are satisfied and the last point calls for a further 0.25 marks penalty, the penalty is disregarded, and 0 marks would be awarded overall.
-Round down to the nearest 0.5 marks. i.e., if you obtain 0.75 marks, 0.5 will be credited.

(o) Briefly explain why is this only an estimate of where the ecliptic actually is. Would any of the above assumptions be not valid on certain days? You may consider alternative perspectives of the definition of the ecliptic. [1.5]

Solution:

The ecliptic can alternatively be defined as the orbital plane of the Earth around the Sun. [0.5]
The moon's orbital plane is inclined by about 5.1 degrees with respect to the ecliptic plane [0.5]
Hence, for certain days, the moon would not be close to the ecliptic. [0.5]

Note:

For point 1: Accept any equivalent alternative definition that demonstrates clearly the link between the word "ecliptic" and the orbital plane of the Earth. Stating only "apparent movement of the sun over one year" or "path of the sun" would not result in any marks being awarded.
For point 2: Exact inclination is not tested. Participants would be awarded the 0.5 marks as long as they state that there is a significant difference in the inclination of the two orbital planes. Marks would not be awarded, however, if any ridiculous inclination is given (more than 15 degrees).
For point 3: Participants must demonstrate clear understanding that it is the assumption related to the moon being close to the ecliptic that may not be valid while for Saturn, the assumption is largely valid (and therefore should not be stated as possible to be non-valid). They would be penalised if they stated that the assumption for Saturn to be close to the ecliptic may not hold. They do not need to explicitly states that the assumption for Saturn would be largely valid as the question did not explicitly ask. They would, however, not be penalised if they have stated so.

Everyone has probably heard about the 12 zodiac signs in astrology. They correspond to 12 zodiac constellations in the night sky, all of which lie along the ecliptic. However, over thousands of years, the effect of axial precession of the Earth has changed the apparent path of the Sun on the celestial sphere. Some now say that a 13^{th} constellation, namely Ophiuchus, should also be included in the zodiac as it lies along the ecliptic. Does anyone know where Ophiuchus is?

(p) On the star chart, trace out and label Ophiuchus. [1]

Solution:

Answer on the starchart as indicated. [1]
No partial credit.

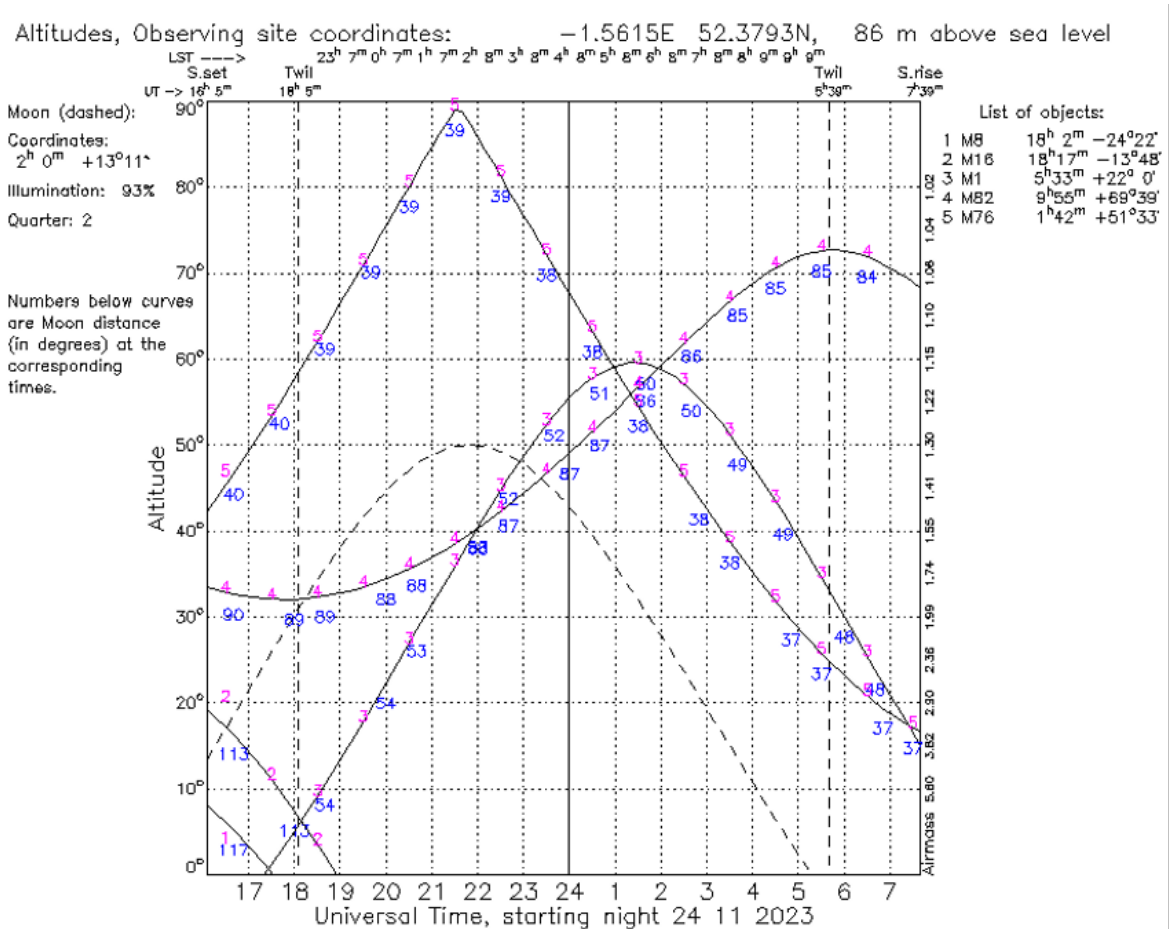
Axial precession is the reason some are proposing a change in the date of zodiac signs. As the dates were originally meant to indicate the days when the Sun is in that constellation, the effect of precession has made the dates not indicative of the position of the Sun. Hence, some propose a new zodiac with 13 signs, including Ophiuchus, with revised dates such that they indicate the dates when the Sun is inside the constellation. However, it has not been adopted as people prefer to continue to subscribe to the original 12 zodiac signs.

Thank you everyone for listening to my night sky talk. I hope that you have learnt something new today and enjoy the night sky away from the bustling city state of Singapore!

Section C Observatory Experience

The graph below shows the altitudes, above horizon, of five deep sky objects (DSOs): M8, M16, M1, M82, M76, plotted against time. The date is 24th November 2023. The Sun sets at 4.05 pm and it gets completely dark at 6.05 pm.

The number above each line refers to the object the line is for. Please refer to the "List of objects" **on the right** for the DSO that each number refer to. The dotted line represents the Moon.



[Turn over]

This observatory has a visible light telescope, and is located in the **United Kingdom**, which follows Coordinated Universal Time (UTC +0). Hence, the local (clock) time follows UTC exactly.

Please refer to the chart on Page 7 to answer parts **(a)** to **(d)**.

(a) **From the chart**, what can you see in the sky at 9.00 pm UTC? [2]

Solution:

Moon, M76, M82, M1.

-In no particular order; trick question.
-Participants need to include Moon as well.
-0.5 marks each.

(b) **From the chart**, which phase is the Moon in? [1]

Solution:

Waxing Gibbous. [1]

-Participants may identify the moon phase by comparing the culmination time of the moon against the supposed local solar midnight (based on sunrise and sunset timing).
-Participants can also note that the quarter is 2: meaning the moon is on the 2nd ¼ of its orbit, hence waxing gibbous.
-Full moon is not accepted as the illumination is only 93%.

(c) **Hence**, explain why it is not a good idea to be looking at M1 at 11.00 pm UTC. [2]

Solution:

M1 has the same altitude as the full moon at 11pm. [1]
Therefore, the brightness of the moon will outshine M1/distort the image of M1. [1]

Accept other reasonable phrasing as long as the participants:
-recognise the close proximity of M1 to the full moon (for the first mark).
-recognise that it is hard to observe dim objects if it is close to the full moon (for the second mark).

(d) The chart can tell us the time that some of the deep sky objects (DSOs) rise or set (go above or below the altitude of 0° over time).

The DSOs mentioned in the graph are: M8, M16, M1, M82, M76.

Using information from the graph, if we want to use the observatory, state the order of DSOs that we should observe over the night. [3]

Note. *Due to technical limitations of the telescope and the obstruction of trees near the horizon, the telescope is unable to view anything below* 20° *in altitude.*

Solution:

M76, M1, M82. [3]

This is in the order of which DSO sets first.
We cannot observe M8 and M16 because they are setting soon and both of them are below the altitude of 20°.

-0.5 marks for each visible object correctly identified.
-1.5 mark for the order (M76 then M1 then M82), ignoring possibly more (wrongly identified as visible) DSOs. The order must be exactly correct for this 1.5 mark to be awarded.
-Penalise 1 mark each if M8 or M16 is stated.
-Lowest possible mark is 0.

You do **NOT** need to refer to the chart to answer the remaining parts.

(e) On the celestial sphere, how do we identify the local sidereal time? Define explicitly any points, lines/curves/circle on the celestial sphere, area of the celestial sphere and concepts related to the celestial coordinate systems in your answer. [2]

Solution:

The local sidereal time is the right ascension that corresponds to the local meridian of the observer. [1]

or

The local sidereal time is the hour angle of the vernal equinox. [1]

At least two correct definitions, based on what was written above: [1]
-Right ascension refers to the lines (hour circles) that connect the North Celestial Pole to the South Celestial Pole.
-Local meridian is one of the Right ascension lines that goes through the zenith and nadir of the observer.
-Hour angle is dihedral angle between the meridian plane and the hour circle.
-Vernal equinox is the equinox on the Earth when the subsolar point appears to leave the Southern Hemisphere and cross the celestial equator, heading northward as seen from Earth.
-Other acceptable answers (see Note below).

NOTE:
-Marks would only be awarded for definition if it is correct, and if it is about lines/points/curves/areas etc on the celestial sphere, and if it is mentioned in the answer to local sidereal time.
-Marks for definition would still be awarded if the local sidereal time is wrong, provided the above condition is satisfied.

(f) State and explain a possible reason why it may be important to know the local sidereal time when operating the observatory telescope to look at a particular DSO of known right ascension. [3]

Solution:

To know if an object is visible in the sky, we compare the local sidereal time of the time period we are planning to observe with the right ascension of the object. [1]
The difference between the object's RA and the local sidereal time would tell you how far the object is away from the local meridian. [1]
Hence, the objects that are about +6 hours from the local meridian would be visible to the observer. [1]

Accept any other convincing reason and explanation.

(g) A list of factors that contribute to observation conditions are listed below. Circle the one that would be more optimal, and explain your answer. [4]

Humidity: high humidity / low humidity
Explanation:

Wind: stable, smooth wind / strong gusting wind
Explanation:

Rain: rain / no rain
Explanation:

Elevation above sea level: at sea level / on a mountain (2000 meters above sea level)
Explanation:

Solution:

Humidity: low humidity [0.5]
Explanation:
One of the following: [0.5]
-Low concentration of water vapour in the air, to reduce the chance of condensation.
-Water vapour obstructs visible light.
-Storms and rainy weather less likely to happen in places of low humidity.

Wind: stable, smooth wind [0.5]
Explanation:
Stable and smooth wind so that the image of the deep sky objects being observed would not be distorted/perturbed by the atmospheric turbulence that affects the refraction of light through atmosphere, which leads to blurred images. [0.5]
(Accept anything along the line of reduced atmospheric seeing.)

Rain: no rain [0.5]
Explanation:
As the dome is open and telescope is exposed to the air, it will get wet if it rains. [0.5]
(Accept other plausible explanation, including concerns about the weather: cloud/fog etc.)

Elevation above sea level: on a mountain (2000 meters above sea level) [0.5]
Explanation:
On the mountain, atmosphere is thinner and there is less atmospheric distortion for visible light. [0.5]

As this observatory is located in the United Kingdom, in November, temperatures change drastically as the Sun sets, falling *significantly* from around 9–10 °C in the evening to around 1–2 °C at night.

(h) Since we are observing objects at infinity, we can adjust the focus of the telescope to a certain point where there is optimal focus of the image, regardless of the object we are looking at. However, in practice, we would still need to adjust the focus *as time passes and the Sun sets*. Explain a possible reason why we need to do so. [3]

Solution:

Drastic change in temperature over time, especially when the sun sets, [1]
causes parts of the telescope to expand/contract, changing the focal length of the telescope. [1]
Hence, we must adjust the focus to correct for that change in the focal length of the telescope. [1]

(j) How do adaptive optics improve the images captured by ground-based observatories? [2]

Solution:

Stars may be blurry due to atmospheric turbulence, hence may not be ideal for viewing by ground-based telescopes. [1]
In adaptive optics, a bright point star would be used to adjust the mirror to correct for the blurriness/image distortions due to atmospheric turbulence. [1]

(k) Lasers are used by observatories, especially those with adaptive optics, as part of the preparation process before they begin to observe DSOs. Why are lasers helpful for adaptive optics? [3]

Solution:

Depending upon where the telescope is pointed in the sky, there may or may not be a sufficiently bright star within the field of view. [1]
Observatories shine a laser into the atmosphere, (by exciting sodium atoms at the upper atmosphere,) to create an artificial, bright guide star. [1]
This artificial star is used as a reference to calibrate the telescope's adaptive optics system and adjust its focus, so that the image appears as a single point source instead of a blurry image. [1]

END OF PAPER