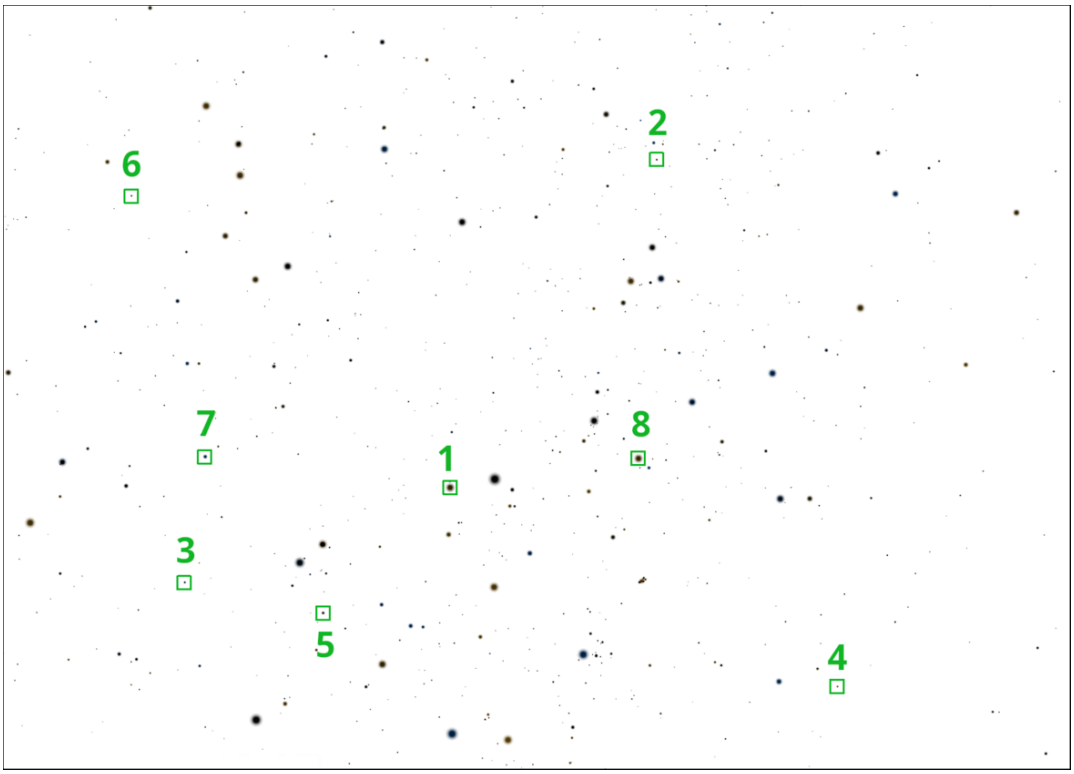
(OM01) **Know your Sky** **[16 marks]**

Use the skymap "Map-OM01" to answer the questions below.

(OM01.1) Mark all the objects listed below with a box (□) around the object. Label each of your marked objects with the corresponding Object No. **4**

Object No.	Object Name	Object No.	Object Name
1	β Aur	5	δ Gem
2	δ Cep	6	β CVn
3	δ Cnc	7	α Lyn
4	δ Cet	8	β Per

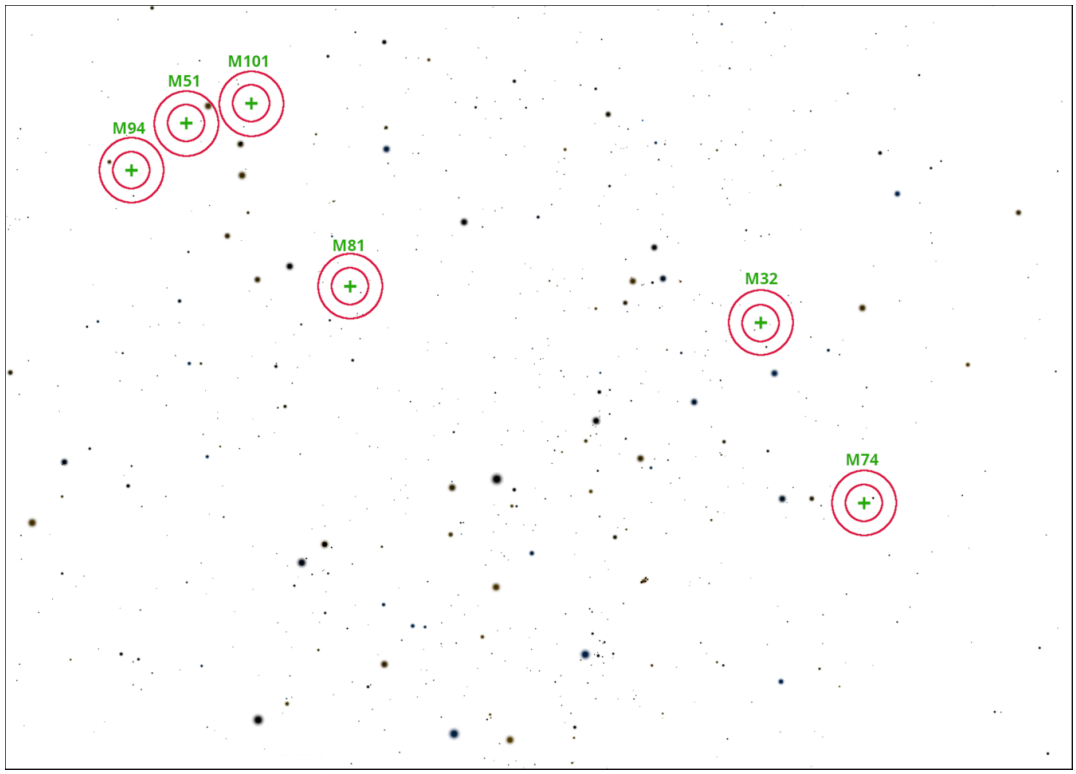
Solution:



Every correct star gets	0.5

(OM01.2) Mark the positions of the following 6 galaxies from the Messier Catalogue using a plus sign (+) and label them with their corresponding Messier number. **6**
M32, M51, M74, M81, M94, M101

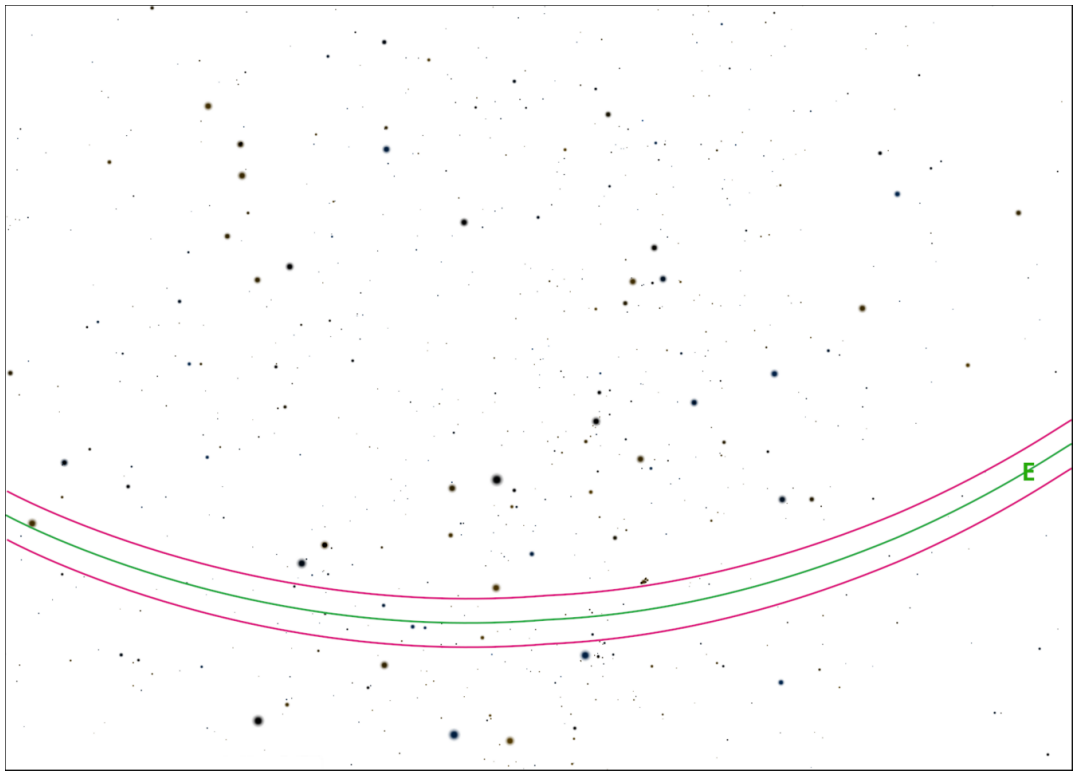
Solution:



Intersection point of each cross inside the inner circle	1.0
Intersection point of each cross between the inner and outer circles	0.5

(OM01.3) Draw the Ecliptic on the map and label it as "E". **2**

Solution:



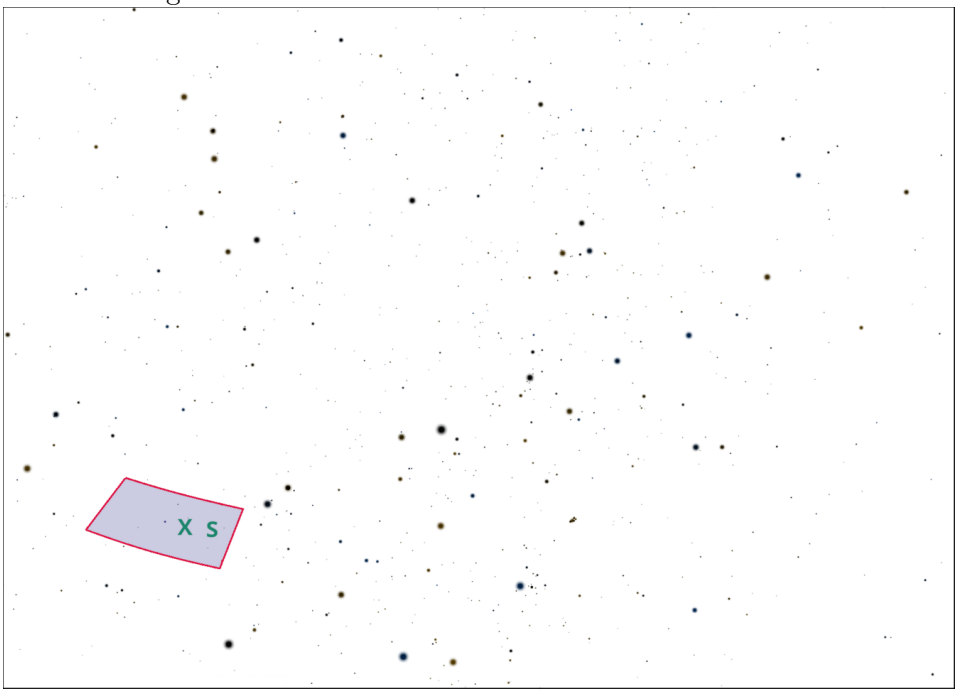
The curve passes within the boundaries of 6 or 5 zodiacal constellations.	1.0
The curve passes within the boundaries of 3 or 4 zodiacal constellations.	0.5
Curve is completely inside the inner bounds.	1.0
$\geq 50\%$ of the curve is inside the bounds.	0.5

If the curve is clearly non-monotonic or not smooth, penalty of -1.0 mark.

(OM01.4) A total solar eclipse occurred on 1 August 2008. At a certain place on Earth the totality occurred at local noon.

(OM01.4a) Mark the position of the Sun at the time of the eclipse with a cross ($\times$) and label it as "S". **1**

Solution:
The date when the eclipse occurred is 1st August. During the start of the month of August the Sun is in the constellation of Cancer.

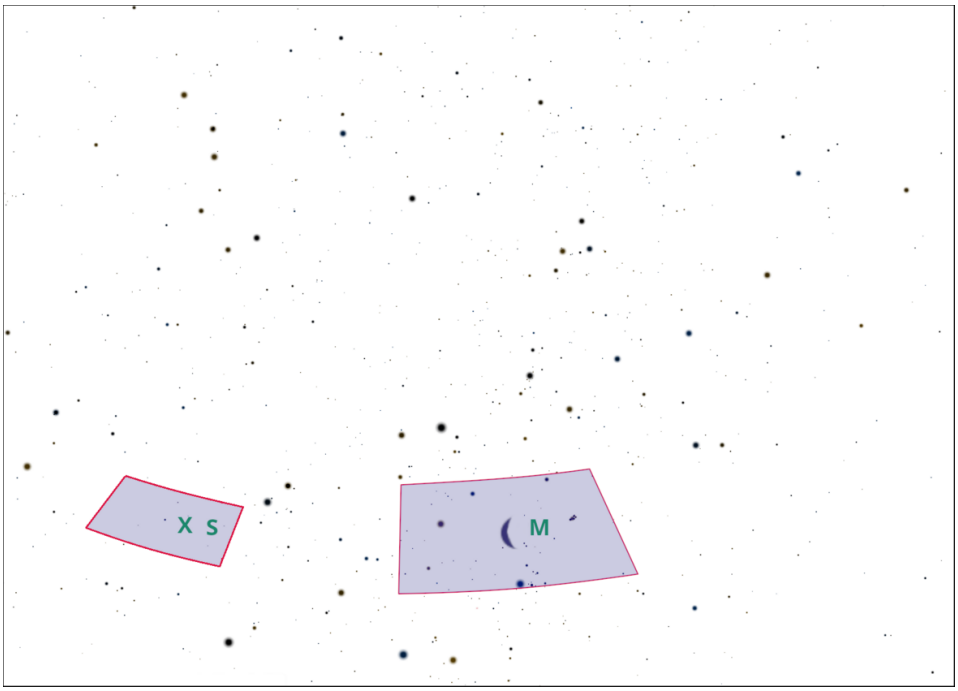


Position of Sun within the box.	1.0
Sun not on the Ecliptic irrespective of whether the Ecliptic is correctly drawn.	0.0
Position of Sun consistent with Ecliptic drawn in previous part and Sun is within Cancer but outside the box.	0.5

(OM01.4b) Draw the Moon at the appropriate position on the map as seen from the same location on 28 July 2008 at local noon, and label it as "M". The drawing should be of appropriate shape and orientation, but need not be to scale. The bright side of the Moon should be shaded. **3**

Solution:
28 July was 4 days before the eclipse occurred.

Moon moves around 13° every day from west to east. Hence, Moon will be around 52° to the east of Sun, almost along ecliptic, i.e. Moon will be in constellation of Taurus.
Phase of the Moon will be crescent (anything less than half is acceptable).
The bright part of the Moon should be towards the Sun.



Crescent of Moon drawn	0.5
Bright part is towards Sun	0.5
Any part of Moon drawing is within the box	1.0
Value of elongation of Moon and Sun, irrespective of position of Sun in the earlier part is around $\approx 52^\circ$or $3.5\,\mathrm{h}$	1.0

(OM02) **Know your Grid** **[16 marks]**

Use the skymap "Map-OM02" to answer the questions below.

The constellation lines and boundaries (as per IAU standards) of two constellations denoted as C1 and C2 are shown in the full-sky map. Alternative depictions of the same constellations according to a few cultures are also shown on the right panel for your reference, if needed. A certain coordinate grid is also shown.

(OM02.1) Identify the constellations C1 and C2 and write their names (of Latin origin) or IAU abbreviations in the table in the Summary Answersheet. **1**

Solution:
It is evident from the constellation lines and their relative positions that –
C1 : Virgo or Vir
C2 : Corvus or Crv

Correct identification of each constellation	0.5

(OM02.2) Three empty red squares and three empty blue circles are shown on the map. There is a grid line passing through each of these squares and circles.

(OM02.2a) The lines that pass through the red squares are lines of constant **1**
Ecliptic latitude (β) / Ecliptic longitude (λ) / Declination (δ) / Right Ascension (α) / Galactic latitude (b) / Galactic longitude (l).
Tick (✓) the correct option in the Summary Answersheet.

Solution:
Since the constellation boundaries are parallel to the grid lines, the grid shown in the figure must be the **Equatorial Grid**.
Circles of declination are centred around the poles. Hence, the lines that pass through red squares are declination (δ) lines.

Correction identification	1.0

(OM02.2b) The lines that pass through the blue circles are lines of constant **1**
Ecliptic latitude (β) / Ecliptic longitude (λ) / Declination (δ) / Right Ascension (α) / Galactic latitude (b) / Galactic longitude (l).
Tick (✓) the correct option in the Summary Answersheet.

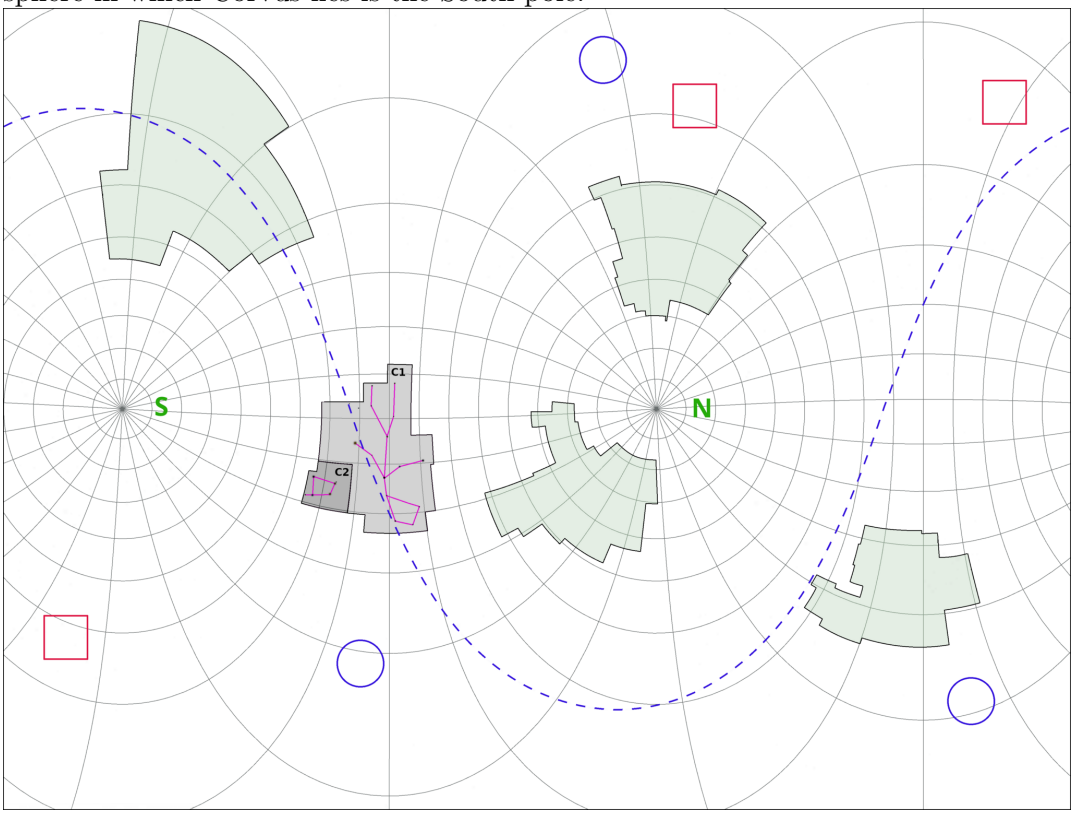
Solution:
Lines emanating from poles and perpendicular to the declination circles are RA lines. Hence, the lines that pass through the blue circles are lines of constant RA (α).

Correction identification	1.0

(OM02.3) Identify the North and South poles of the grid. Label these points as "N" and "S", respectively on the map "Map-OM02". **1**

Solution:

Constellation of Corvus is towards the South of Virgo. Hence, the pole of the hemisphere in which Corvus lies is the South pole.



Correct identification of each pole	0.5

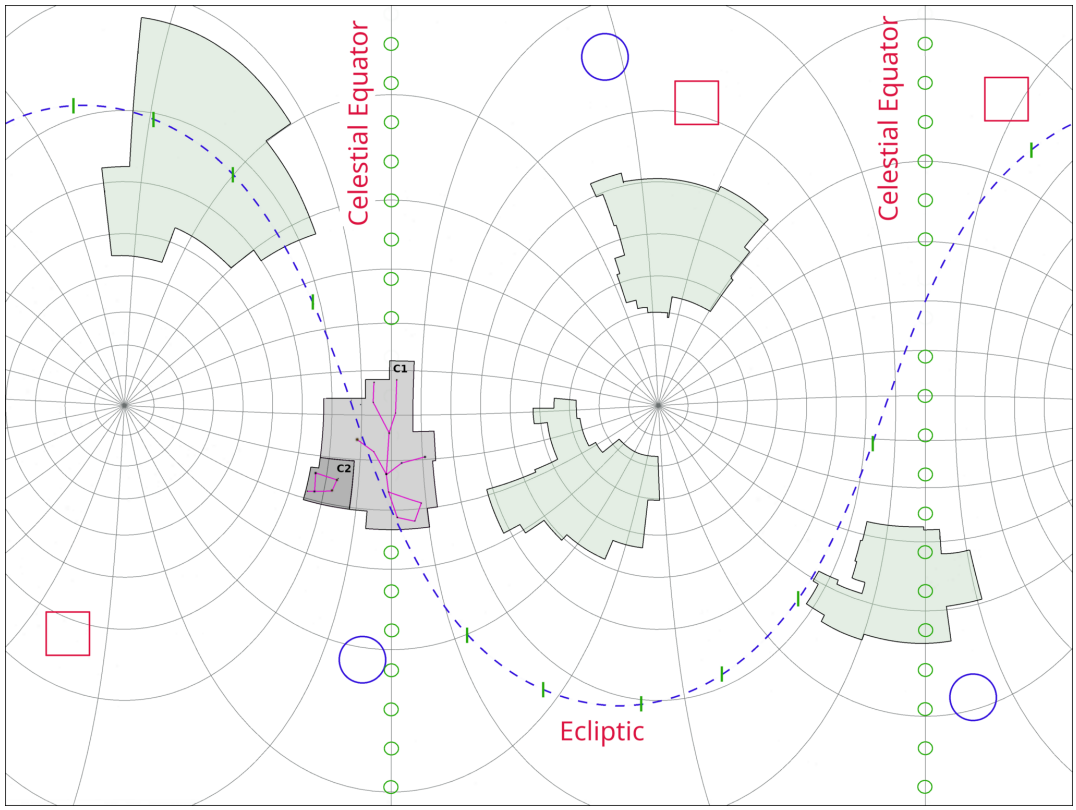
(OM02.4) Two of the following are present in the given sky map. Identify these by marking with appropriate symbols (shown below) on the corresponding entire curve/line. **2**

(i) Ecliptic (small bars like ⊣⊣⊣)

(ii) Celestial Equator (small circles like ⊸⊸⊸)

(iii) Galactic Equator (small crosses like ⤫⤫⤫)

Solution:

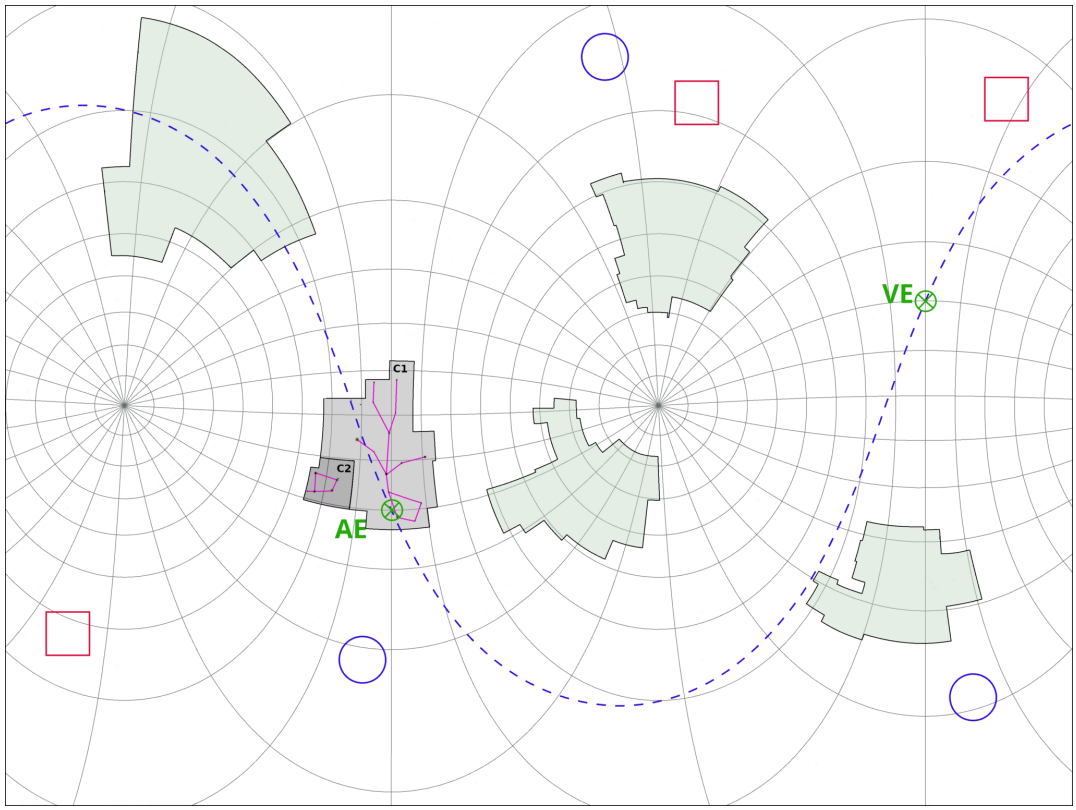


Ecliptic marked correctly	1.0
Celestial Equator marked correctly	1.0
If only one segment of Celestial Equator is marked	0.5

(OM02.5) Mark the Vernal Equinox (VE) and Autumnal Equinox (AE) on the grid with ⊗ and write VE and AE beside them, respectively. **2**

Solution:

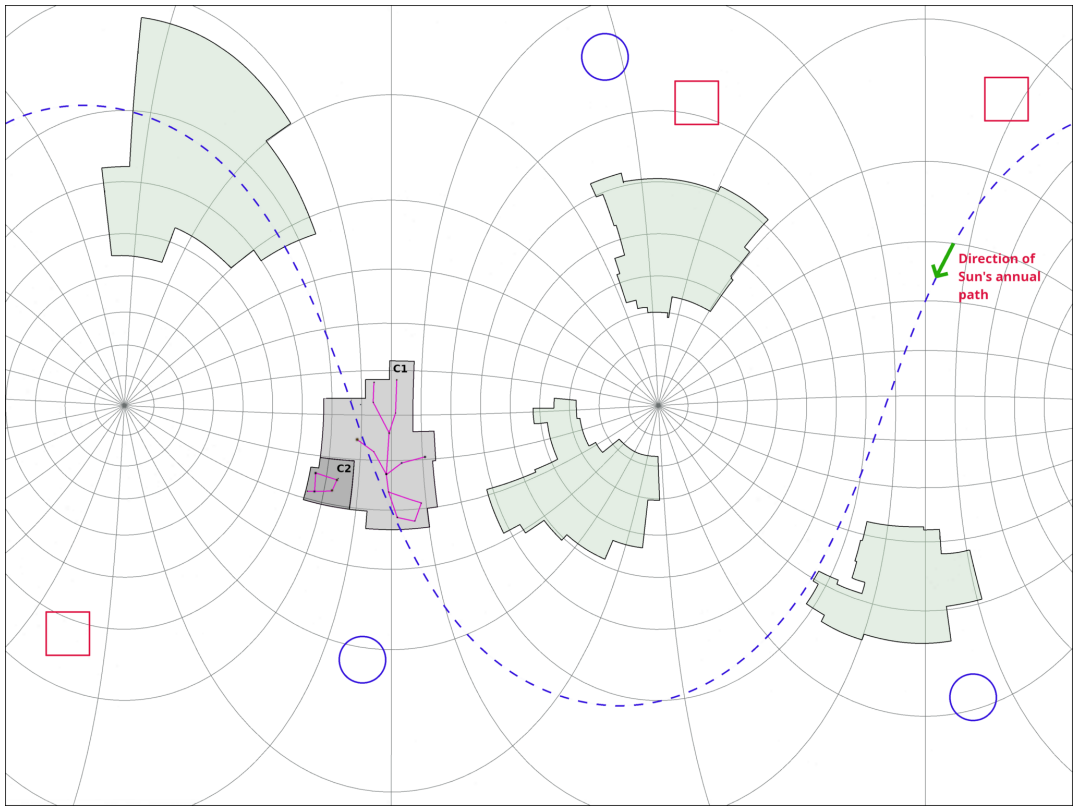
Equinoxes are intersection points of the equator and ecliptic. Autumnal equinox (AE) lies in the constellation of Virgo. Hence the other intersection point is Vernal equinox (VE).



Equinoxes are marked at intersections of CE and Ecliptic	1.0
Correctly identified of both the equinoxes	1.0

(OM02.6) Indicate the direction of the Sun's annual motion by drawing an arrow close to the Vernal Equinox. **1**

Solution:
From VE the Sun moves northward, Sun's motion is in the direction of increasing RA.



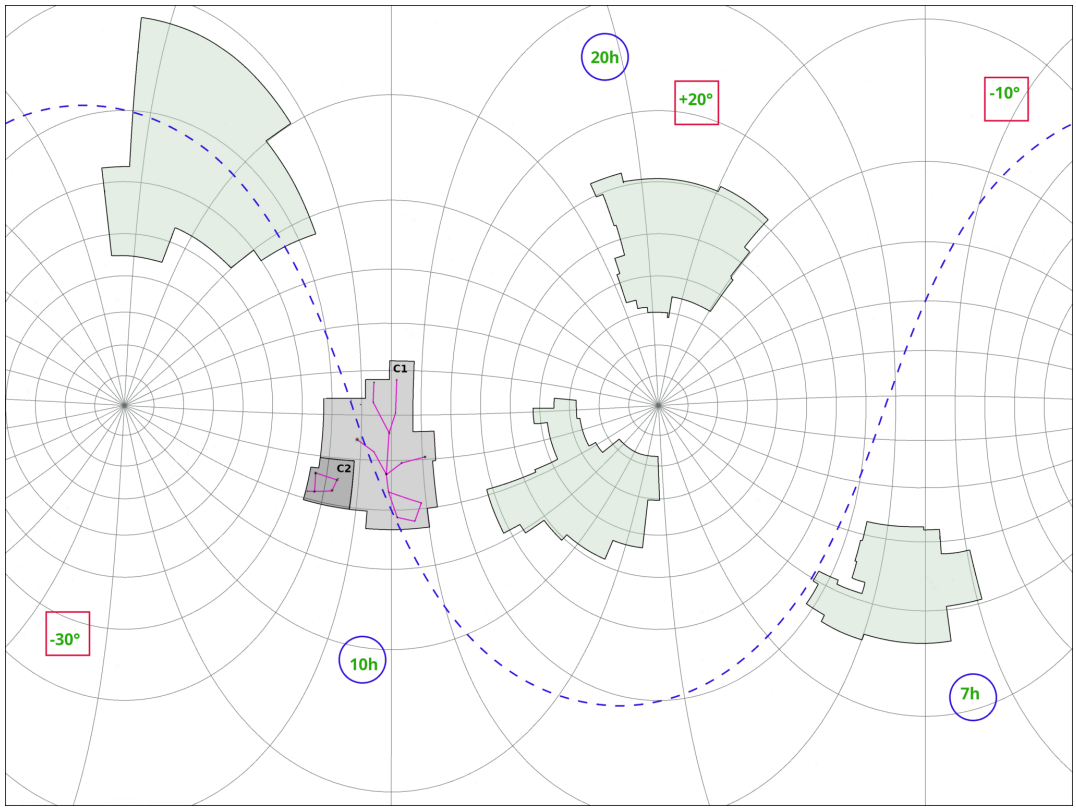
Correct direction	1.0

(OM02.7) Write the values, in appropriate units, inside each red square and blue circle given on the "Map-OM02", of the corresponding grid lines passing through them. **3**

Solution:

The Vernal Equinox (VE) and Autumnal Equinox (AE) are identified in part (OM02.5). The Right Ascension (RA) of the VE is 0 h, while the RA of the AE is 12 h. From part (OM02.6), it is seen that the Sun moves northward in the direction of increasing RA, which allows the RA circles to be marked accordingly. RA is conventionally measured in hours, minutes, and seconds.

The celestial pole has a declination of 90°, with the convention that northern declinations are considered positive and southern declinations are considered negative. Declinations are measured in degrees, arcminutes, and arcseconds.



Each correct value with appropriate sign and in appropriate units	0.5
Incorrect values but with appropriate sign and units and consistent with (OM02.2a) and (OM02.2b) – maximum	1.5

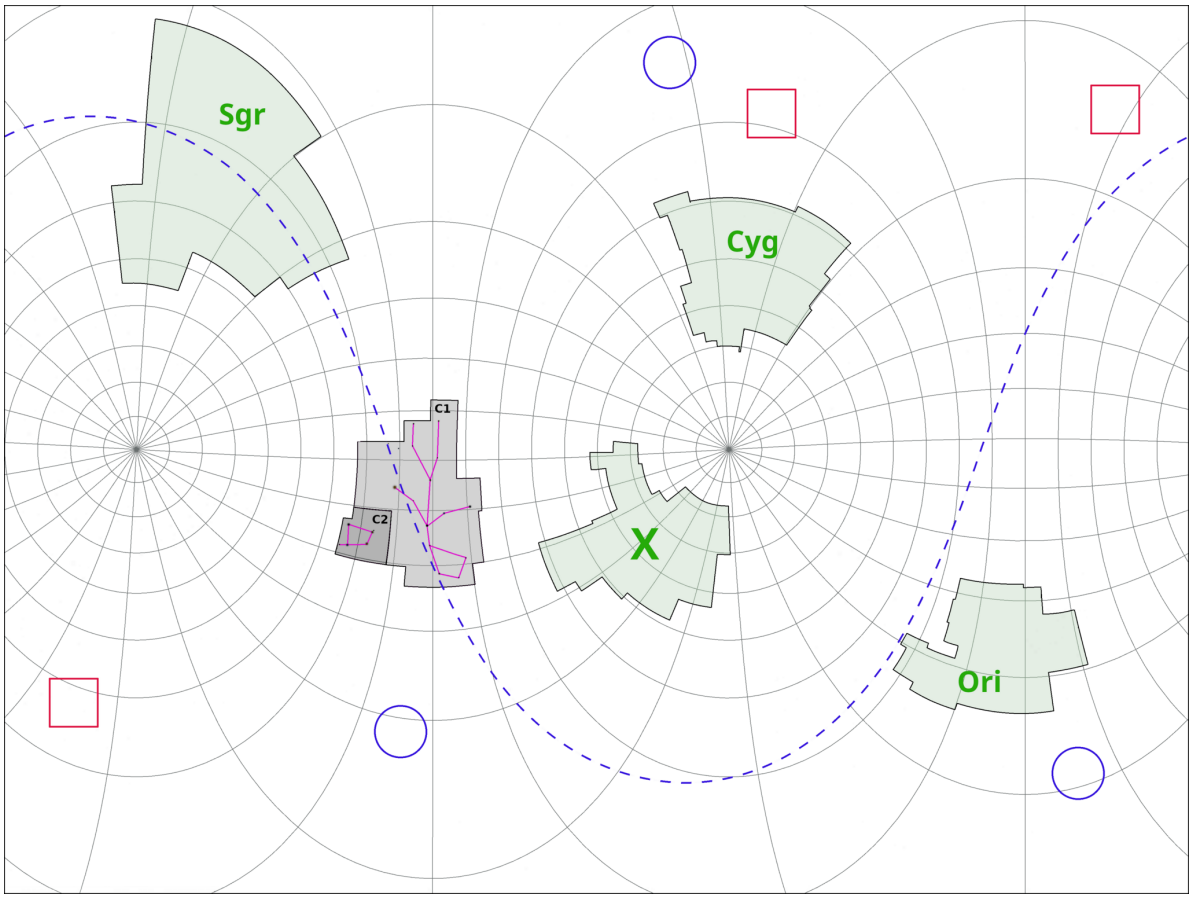
(OM02.8) The location of 4 constellations (apart from C1 and C2) are shown on the grid by light-green shaded areas. Consider the following list of constellations. **4**

Aquarius (Aqr), Cygnus (Cyg), Leo (Leo), Orion (Ori), Perseus (Per), Sagittarius (Sgr).

On the map "Map-OM02", label the appropriate shaded areas with the IAU abbreviations of the constellations that are present in the above list. Mark a cross (×) on those shaded areas, if any, which do not appear in the above list.

Solution:

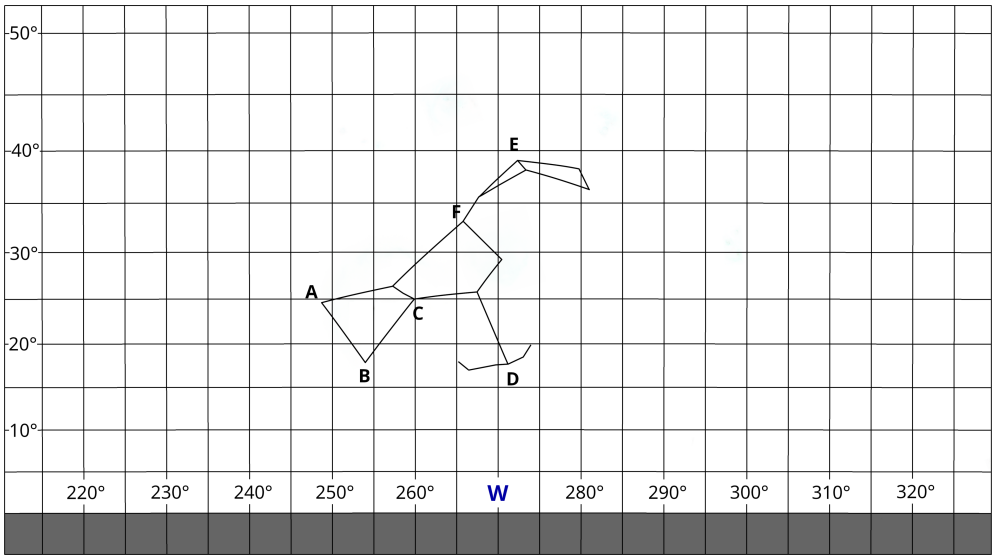
- In the given list there are 3 zodiacal constellations, Aquarius, Leo and Sagittarius, which implies that they should lie on the Ecliptic.
- The Ecliptic passes through the constellation to the top left which is about 2 hours ahead in RA from Virgo, hence it is Sagittarius.
- From the given list Leo and Orion are the constellations which lie on the Celestial Equator. Hence, the constellation on the lower right has to be Orion.
- Out of the remaining constellations, i.e. Perseus and Cygnus, the constellation of Cygnus lies between RA 20h and 22h.
- The remaining box is of Ursa Major which is not present in the given list.



Each correct identification (including marking $\times$, or "UMa")	1.0

(OM03) **Know your Time** **[18 marks]**

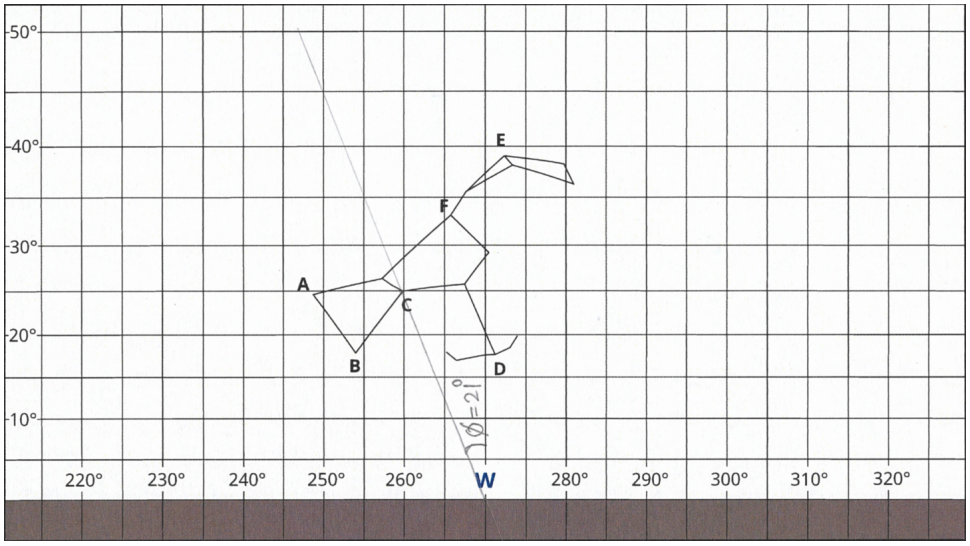
The given sky map (in Mercator projection) shows the constellation of Orion as seen from a certain location X (longitude $\lambda_X = 70°\,\text{E}$) on 21 March 2025 at 22:00 local time. The point "W" marks the cardinal West point. The altitude and azimuth values are marked on the grid.



(OM03.1) What is the approximate latitude (ϕ_X) of the location X? **4**

Solution:

Draw the celestial equator (line passing through W and Mintaka (δ Ori).
Measure the angle ϕ_X between the Celestial Equator and the vertical at 270° azimuth.



$\phi_X = 21°\,\text{N}$ 1.0

Half credit lower limit	Full credit range	Half credit upper limit
19°	20° to 22°	23°

Drawing the equator	0.5
Equator passing through Mintaka (point C)	1.0
Indication of hemisphere either through "+", or "N", or "North"	1.5

(OM03.2) The grid provided on the Summary Answersheet has the same projection (Mercator), and **14**

the angular scale in both azimuth and altitude are identical to that of the grid provided in the question. On this grid draw to scale the constellation of Orion as it will be at another location Y (with latitude $\phi_Y = 40°$ S and longitude $\lambda_Y = 50°$ W) on 21 January 2026 at 18:00 local time. An approximate outline of the constellation is enough, with the points A–F being marked clearly. Identify the cardinal point "P" shown on the grid (tick (✓) the appropriate box in the Summary Answersheet). You may make suitable approximations to arrive at your answer.

You may use the following relations between the Hour Angle (H), Declination (δ), Altitude (a), Azimuth (A) and Latitude (ϕ):

$$\cos H = \frac{\sin a - \sin\delta \sin\phi}{\cos\delta \cos\phi}$$

$$\sin\delta = \sin\phi \sin a + \cos\phi \cos a \cos A$$

Solution:

The star Mintaka (which lies very close to the Celestial Equator, i.e., $\delta \approx 0°$) has an approximate altitude at X at 22:00 hrs on 21 March $a_{\mathrm{X,21Mar,22:00}} = 25°$ from the West horizon.

Therefore its hour angle at 22:00 hrs local time on 21 March is given by

$$\begin{aligned} H_{\mathrm{21Mar,22:00}} &= \cos^{-1}\left[\frac{\sin 25° - \sin 0° \sin 20°}{\cos 0° \cos 20°}\right] \\ &= 63.27° \end{aligned}$$

Therefore, the hour angle of Mintaka at 22:00 hrs local time on 21 Jan 2026 (306 days later) will be

$$\begin{aligned} H_{\mathrm{21Jan,22:00}} &= H_{\mathrm{21Mar,22:00}} + 306 \times \frac{360°}{365.2564} \\ &= 63.27° + 301.60° = 364.87° \equiv 4.87° \end{aligned}$$

The hour angle of Mintaka at 18:00 hrs local time on 21 Jan 2026 will be

$$\begin{aligned} H_{\mathrm{21Jan,18:00}} &= H_{\mathrm{21Jan,22:00}} - 4 \times \frac{360°}{24} \\ &= 4.87° - 60° = -55.13° \end{aligned}$$

The hour angle of an object at a certain local time on a given day will be the same at all locations.

Since the hour angle is negative, it indicates that Mintaka is to the east of the meridian at 18:00 hrs local time.

Therefore, the point P represents the cardinal point East.

The altitude of Mintaka at 18:00 hrs local time on 21 Jan 2026 at the location Y will be

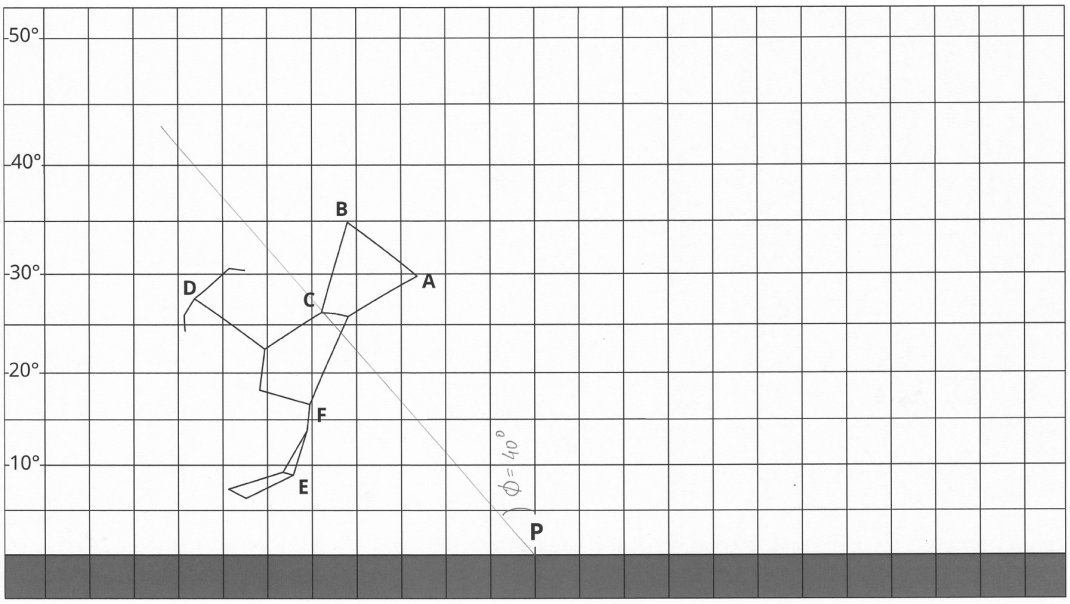
$$\begin{aligned} a_{\mathrm{Y,21Jan,18:00}} &= \sin^{-1}\left[\cos H_{\mathrm{21Jan,18:00}} \cos\phi_Y\right] \qquad \text{since } \delta \approx 0 \\ &= \sin^{-1}\left[\cos(-55.13°)\cos(-40°)\right] \\ &\approx 26° \end{aligned}$$

Now, the location Y lies in the Southern hemisphere. The Celestial Equator lies towards the North (i.e., tilted towards the left of the cardinal point E in the given projection) near the Eastern horizon in the Southern hemisphere.

Further, the latitude of Y is 40° S, which gives the inclination of the Celestial Equator w.r.t. the vertical at 90° azimuth.

The position of Mintaka will be nearly on the Celestial Equator at an altitude of $\approx 26°$.

The orientation of Orion can be inferred by realizing that the shield of Orion is ahead of the belt as the sky moves.



"P" marked as "E"	2.0
Angle of line joining Mintaka (C) and cardinal point (P) w.r.t. vertical, between 37° to 43°	2.0
Angle of line joining Mintaka (C) and cardinal point (P) w.r.t. vertical, between 35° to 37° or between 43° to 45°	1.0
All 6 of A–F points lie to the left of the vertical at 90° azimuth	2.0
Only 5 among A–F points lie to the left of vertical at 90° azimuth	1.0
Only 4 among A–F points lie to the left of vertical at 90° azimuth	0.5
Altitude of Mintaka (point C) between 24° to 28°	2.0
Altitude of Mintaka (point C) between 22° to 24° or between 28° to 30°	1.0
Shield (point D) at lesser azimuth than belt (point C)	2.0
Legs (points A and B) are south of Celestial Equator	2.0
Scale: Distance of B–F is between 1.8 cm and 2.8 cm	2.0
Scale: Distance of B–F is between 1.3 cm and 1.8 cm or between 2.8 cm and 3.3 cm	1.0