4th Japan Astronomy Olympiad National Finals
Practical Solutions

Problem 1

Question 1

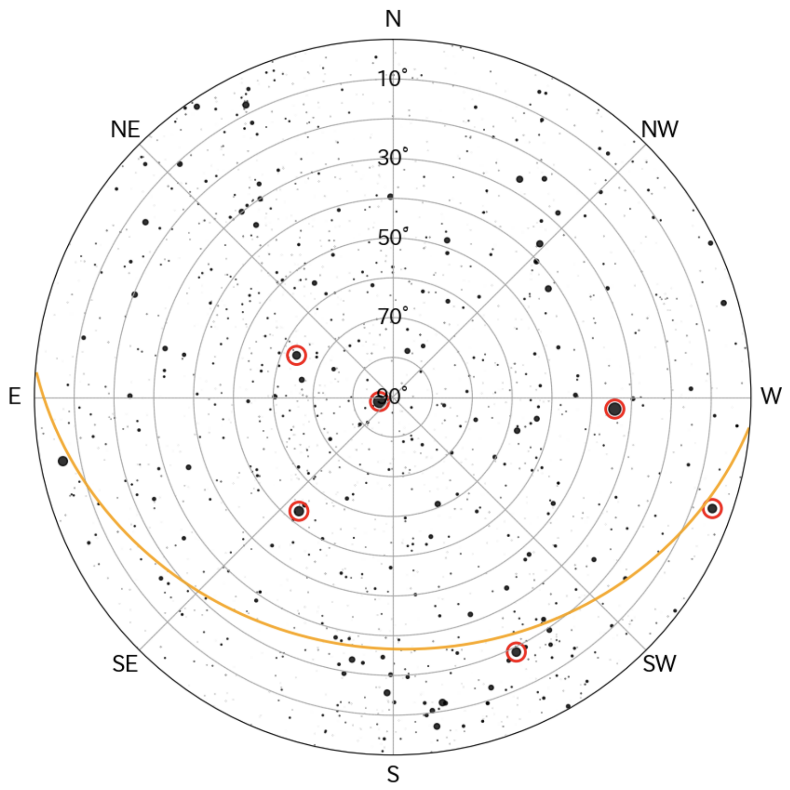
(1) 40°

(2) Lyr

(3)

M 4	M 31	M 37	M 57	M 81
◯	◯	×	◯	◯

(4) Refer to the figure below



(5) Altitude h: 32°, Azimuth A: $1^{\mathrm{h}}\,20^{\mathrm{m}}$

(6) Right ascension: $17^{\mathrm{h}}\,11^{\mathrm{m}}$, Declination: $-16°$

(7) 00:56 (JST)

Question 2

(1) Magnification: $2 \times 10^2\times$, True field of view: $15'$

(2) Jupiter appears approximately $\frac{1}{25}$ the size of the telescope's field of view. Combined with the result of (1), Jupiter's angular diameter is

$$15' \times \frac{1}{25} = 0.60' = 0.01^\circ = 1.74 \times 10^{-4} \text{ rad.}$$

Using $\tan\theta \approx \theta$ for sufficiently small θ, Jupiter's diameter is

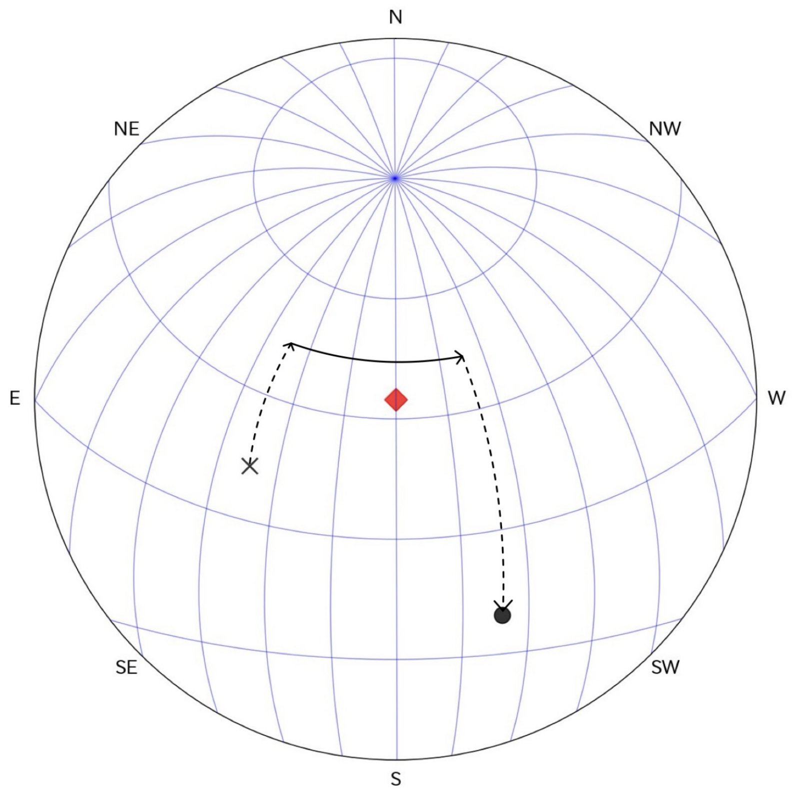
$$5.0 \text{ au} \times \frac{1.5 \times 10^8 \text{ km}}{1 \text{ au}} \times 1.74 \times 10^{-4} = 1.31 \times 10^5 \text{ km.}$$

Therefore Jupiter's radius in Earth radii is

$$\frac{1.31 \times 10^5 \text{ km}/2}{6.4 \times 10^3 \text{ km}} = 1 \times 10.$$

(3) 13.8 magnitudes

(4) See figure: equatorial mount slew path indicated with solid and dashed arrows.



Problem 2

(1) Consider triangle $\triangle OPS$ in the figure in the problem statement, and let $\angle OPS = \alpha$. First, the radial velocity is

$$V_r = V \sin\alpha - V_0 \sin l.$$

Next, by the law of sines,

$$\frac{\sin l}{R} = \frac{\sin\alpha}{R_0}.$$

Substituting, we get

$$V_r = V \sin\alpha - V_0 \frac{R\sin\alpha}{R_0},$$

and therefore

$$\boxed{V(R) = \left(\frac{V_r}{\sin l} + V_0\right)\frac{R}{R_0}.}$$

(2) For each object in Table 2–1, the line defined by the $V(R)$–R relation from (1) is drawn on Figure 2–1, and its intersection with the rotation curve gives R.

No.	R [kpc]	
1	3.0	(acceptable range: 2.6–3.4)
2	5.9	(acceptable range: 5.5–6.3)
3	8.6	(acceptable range: 8.2–9.0)
4	7.8	(acceptable range: 7.4–8.2)
5	8.6	(acceptable range: 8.2–9.0)
6	9.5	(acceptable range: 9.1–9.9)
7	9.5	(acceptable range: 9.1–9.9)
8	11.1	(acceptable range: 10.7–11.5)

Note: Full marks were awarded for answers within the ranges shown in parentheses.

(3) Using galactic longitude l and the values of R from (2), the candidate distance(s) d from the Solar System to each object are:

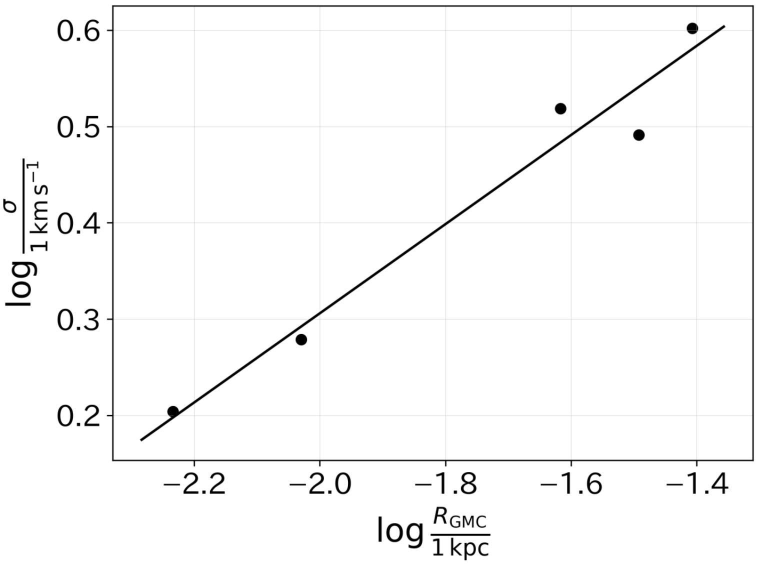
No.	Candidate d [kpc]	
1	5.2 (4.7–5.7),	10.7 (10.2–11.1)
2	4.1 (2.9–5.7),	7.1 (5.6–8.3)
3	2.9 (1.6–3.9)	
4	2.9 (1.9–4.7),	0.9 (0.0–2.0, or none)
5	7.0 (6.0–7.8)	
6	10.9 (10.3–11.5)	
7	13.2 (12.6–13.7)	
8	17.9 (17.4–18.3)	

Note: Full marks were awarded for answers within the ranges shown in parentheses.

(4)

(a) By $\log\left(\dfrac{\sigma}{1\ \mathrm{km\,s^{-1}}}\right)$ vs. $\log\left(\dfrac{R_{\mathrm{GMC}}}{1\ \mathrm{kpc}}\right)$ for GMCs outside the Solar orbit (Nos. 3–8) on answer graph paper ①, and fitting a straight line, the constants are estimated as follows:

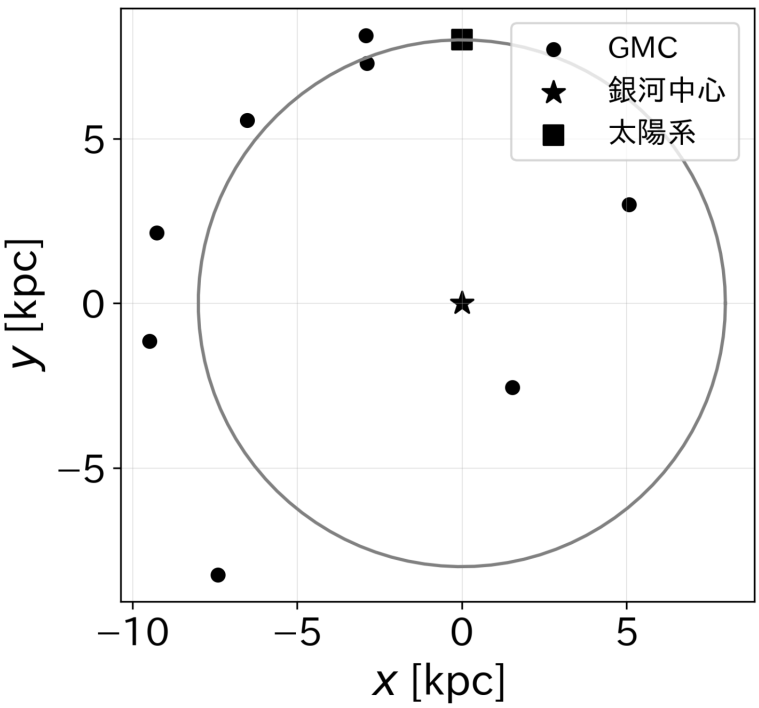
	Answer	Full-mark range	Partial-mark range ($\geq$ 50%)
Estimated C	16.3	(11.0–21.0)	(5.0–30.0)
Uncertainty in C	3.8	(2.0–6.0)	(1.0–10.0)
Estimated α	0.45	(0.30–0.60)	(0.20–0.80)
Uncertainty in α	0.06	(0.04–0.10)	(0.01–0.20)



(b) Using the R_{GMC}–σ relation from (a), the distance d from the Solar System for GMCs inside the Solar orbit is uniquely determined as:

No.	d [kpc]
1	10.7
2	7.1
3	2.9
(4)	(2.9)

(5) All GMC positions plotted together with the Solar System (square marker) and galactic center (star marker), as viewed from the galactic north pole.


GMC
銀河中心
太陽系
5
0
−5
y [kpc]
−10
−5
0
5
x [kpc]