Planetarium Round: Procedure

You will have 30 minutes to read the questions and prepare, 30 minutes inside the planetarium and 30 minutes to process your observations and complete the answer sheet.

The preparation area is outside the planetarium. Go to the table matching the name of your team for the Group Competition. It will also be marked with the sector, row and seat number assigned to you inside the planetarium.

Open the envelope only when the supervisor gives the command to 'START'. You have 30 minutes, the supervisor will give the remaining time e.g. "10 minutes left", "2 minutes left". On the command 'STOP', stop working but do not leave your place until you are shown the 'GO NOW' sign. Take only your question papers, clipboard and pen/pencil (leave the atlas). Follow the directions into the planetarium keeping your distance from other participants and take your place. Do not talk to other participants.

During the tasks you may stand up to get a better view, but do not move around, change seats, talk to other participants, or shine your light at others or at the sky. **The light must be pointed down at all times.**

The round is in 3 parts of 10 minutes each. The first part is for task 1. The second part is for task 2. The third part is for task 3. At 5, 2 and 1 minute before the end a warning will appear briefly on the sky.

At the end of the round wait in your seat until shown the 'GO NOW' sign. Follow the directions to the processing area and find the table matching your team as before (leave the light). Keep your distance from other participants and do not talk to them. After everybody is seated you will have 30 minutes to process your observations and complete the answer sheet (there will be a calculator, geometrical instruments etc. and a clock displaying the remaining time). At the end of 30 minutes place your answer sheets in the envelope and wait at your desk until told to leave the area.

Planetarium Round 1: 'Knowledge of the sky'

The projector will display the sky as seen from near the equator (0°N, 19°E). The rotation of the sky will be stopped for about 2 minutes for part (a), then it will start to rotate for parts (b) and (c). The objects for parts (b) and (c) will be displayed simultaneously.

(Projection time 10 minutes)

(a) A meteor shower will be visible in the sky. Determine the constellation of the radiant and estimate its right ascension and declination coordinates.

Constellation	right ascension	declination

(3 points)

(b) Identify which of the following variable stars visible in the sky are in low (write 'DIM') or high (write 'BRIGHT') brightness states. The mean magnitude as shown in the atlas and the magnitude range are given for each star.

Name	atlas mag.	mag. range	DIM / BRIGHT
γ Cas (*Cih*)	2	1.6 — 3.0	
δ Cep	4	3.5 — 4.4	
μ Cep (*Erakis*)	4	3.4 — 5.1	
β Per (*Algol*)	2	2.2 — 3.4	
o Cet (*Mira*)	3.5	2.0 - 10.1	
χ Cyg	4.5	3.3 - 14.1	
L^2 Pup	4.5	2.6 — 6	
δ Sco (*Dschubba*)	2	1.6 — 2.3	

(8 points)

(c) Identify the constellations whose borders are marked and give their IAU abbreviations.

(9 points)

(Total: 20 points)

Solution

(a) 1 point for each field (total 3)

Constellation	right ascension	declination
Aqr	22:30 ± 0.5h	$-15^\circ \pm 8^\circ$

(b) 1 point for each correct DIM/BRIGHT (total 8)

Name	atlas mag.	mag. range	DIM / BRIGHT
γ Cas (*Cih*)	2	1.6 — 3.0	DIM
δ Cep	4	3.5 — 4.4	DIM
μ Cep (*Erakis*)	4	3.4 — 5.1	DIM
β Per (*Algol*)	2	2.2 — 3.4	DIM
o Cet (*Mira*)	3.5	2.0 - 10.1	BRIGHT
χ Cyg	4.5	3.3 - 14.1	BRIGHT
L^2 Pup	4.5	2.6 — 6	BRIGHT
δ Sco (*Dschubba*)	2	1.6 — 2.3	BRIGHT

(c) Cet (1pt), Cae (1pt), Pup (1pt), Crt (1pt), Mus (1pt), Ser (2pt), CrA (1pt), Equ (1pt). (total 9)

Planetarium Round 2: 'Retrograde Mars'

The projector will display Mars moving relative to the background stars over one season of visibility (1.5 years) starting from the heliacal rising, chosen so that Mars will be at maximum ecliptic latitude at opposition.

The ecliptic will also be displayed, marked with the positions of the Sun during the year and the current date. The Sun will always be below the horizon.

Synodic period of Mars = 780 days.

(Projection time 10 minutes)

(a) Record the following quantities:

i.	the dates of quadrature (when the elongation of Mars is 90°)	
ii.	the date of the beginning of retrograde motion	
	and the date of the end of retrograde motion	
iii.	the date of opposition	
iv.	the ecliptic latitude at opposition	
v.	the width in ecliptic longitude of the loop made by the planet	

(8 points)

Based on your observations and assuming the orbits of Earth and Mars are circular,

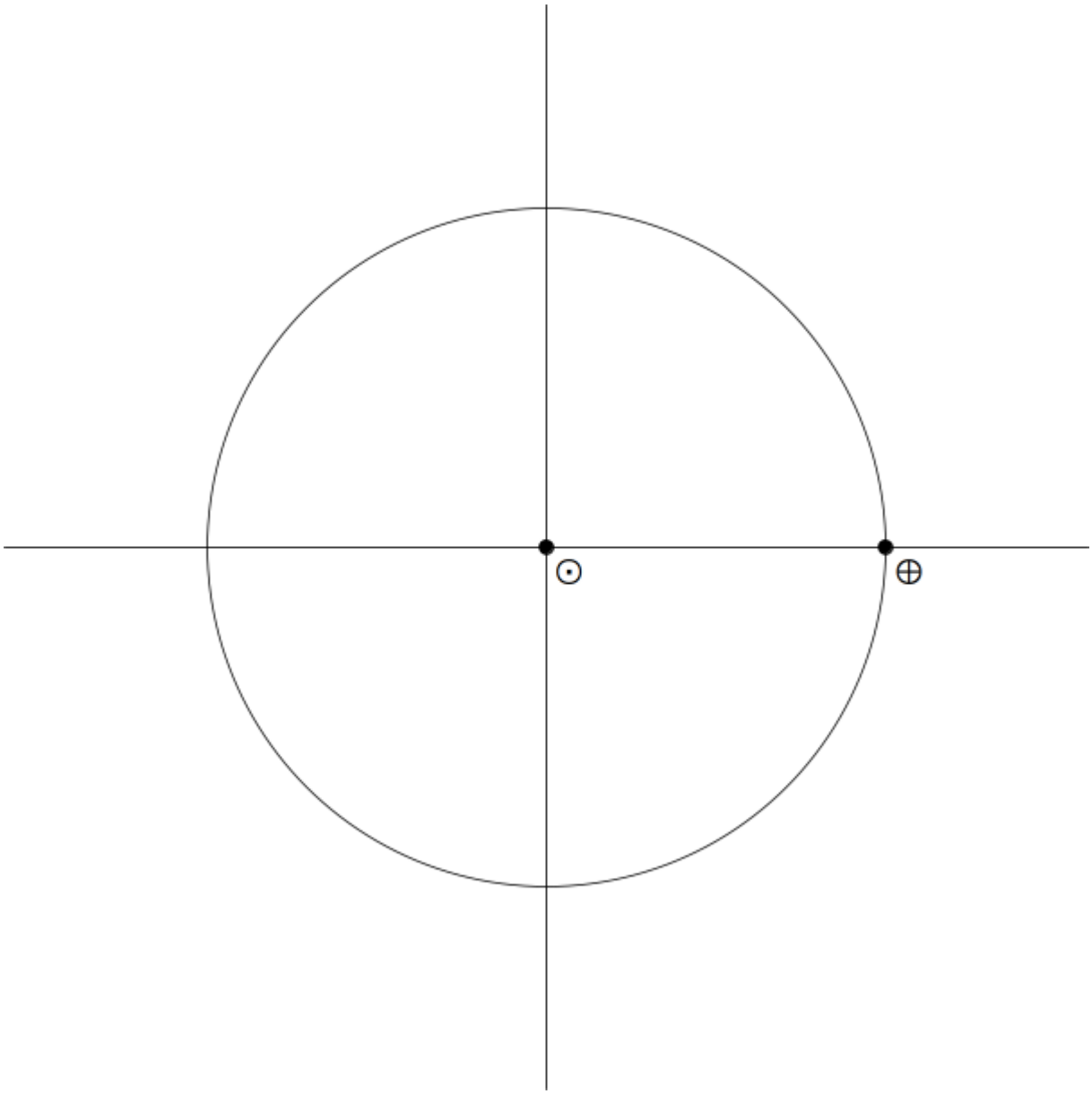
(b) On the answer sheet, mark the positions of the Sun, Earth and Mars at the moments of opposition and quadrature in the heliocentric system and determine the radius of the orbit of Mars in a.u. geometrically, without using Kepler's Laws. Show your method in the answer sheet.

(9 points)

(c) Derive the inclination of the orbit of Mars to the ecliptic. (3 points)

(Total: 20 points)

Answer Sheet



Solution

(a) 2 points for correct date of opposition and 1 point for each other answer (total 8)

i.	the dates of quadrature (when the elongation of Mars is 90°)	8 Nov 1915 ± 5 days
		15 May 1916 ± 5 days
ii.	the date of the beginning of retrograde motion	1 Jan 1916 ± 5 days
	and the date of the end of retrograde motion	21 Mar 1916 ± 5 days
iii.	the date of opposition	20 Feb 1916 ± 5 days
iv.	the ecliptic latitude at opposition	4.5° ± 1°
v.	the width in ecliptic longitude of the loop made by the planet	19° ± 2°

(b) radius 1.5 au.

(c) inclination 1.5°.

Planetarium Round 3: 'TRAPPIST-1'

Aliens have found out that Earth's astronomers discovered planets in the TRAPPIST-1 system by observing numerous transits. They have used their flying saucer (similar to the one you were in for the observation round) to take you to the 5th planet (designated f) of TRAPPIST-1, and have asked you to show them the methods Earthlings use to uncover the parameters of the system. A clock displaying time in Earth hours will be visible. The whole presentation lasts 520 h (1 s represents 1 h).

(Projection time 10 minutes)

Based on your observations (you can use the space on the last sheet for observing notes),

(a) determine the following quantities for the planet you are on (use Earth hours for the times): (7 points)

i. length of the sidereal day [h]	
ii. orbital period [h]	
iii. length of the 'solar' day [h]	
iv. circular orbit	YES / NO
v. obliquity (axial tilt)	

(b) and the following quantities for each planet b, c, d and e: (16 points)

	b	c	d	e
synodic period [h]				
maximum elongation [°]				

(c) calculate the orbital period in hours and the semi-major axis in *tau* (where 1 tau = "TRAPPIST-1f astronomical unit" = the semi-major axis of the orbit of TRAPPIST-1f) of each planet: (8 points)

	b	c	d	e
orbital period [h]				
semi-major axis [tau]				

(d) The term 'gravitational resonance' is used to describe the phenomenon when ratio of the orbital periods of two planets in a system is close to the ratio of two integers. The table below lists some of the resonances observed in the TRAPPIST-1 system. Find which pair(s) of planets correspond to each of the listed resonances if any.

(4 points)

Resonance	Pair of planets
3:2	
8:5	
5:3	
8:3	
4:1	
6:1	

(Total: 35 points)

Solution

(a)

i. length of the sidereal day [h]	221 ± 5
ii. orbital period [h]	221 ± 5 (the same)
iii. length of the 'solar' day [h]	infinity
iv. circular orbit	YES
v. obliquity (axial tilt)	0 ($\leq 1°$)

For determining the orbital period – 3 points, for other quantities – 1 point each.

(b)

	b	*c*	*d*	*e*
synodic period [h]	43.6 ± 2	78.9 ± 2	173.5 ± 2	433.8 ± 2
maximum elongation [°]	17.5 ± 2	24 ± 2	37 ± 2	49 ± 2

(c)

	b	*c*	*d*	*e*
orbital period [h]	36.2 ± 2	58.1 ± 2	97.2 ± 2	166.4 ± 2
semi-major axis [tau]	0.30 ± .02	0.41 ± .02	0.60 ± .03	0.75± .04

(d)

Resonance	Pair of planets
3:2	e/d and f/e
8:5	c/b
5:3	d/c
8:3	d/b
4:1	e/b
6:1	f/b

Each resonance for 0.5 point, apart from f/e, which is worth 1 point.