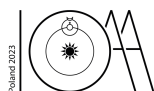


Group Competition



UKR-S1 G-0 I-1

IO-1

English (Official)

Instructions

- For this round, the participants will be grouped by random selection into 5-person teams, each representing a named asteroid. Each participant in the group will be from a different country. The selection will take place near the beginning of the IOAA, so that the team members can get to know each other.
- Please remember the name and number of your asteroid, as this will also be used to identify your place during the Planetarium and Observation rounds.
- The group competition consists of several tasks, which you will receive in a sealed envelope. Each team works together at one table under the supervision of the guides to solve the tasks. You are not allowed to communicate with participants from other teams during the round.
- Dedicated answer sheets are provided for writing your answers. Enter the final answers into the appropriate boxes in the answer sheet (marked A).
- Open the envelopes on the START signal given by the judges. Time is measured from this moment; the winning team will be the one which finishes in the shortest total time, after any time penalties (for example for incorrect or missing answers) are applied. The time penalties are explained in each task.
- When you have solved all the problems, hand your answer sheets to the guide, who will note the total time.
- The maximum time available for the round is 90 minutes. After this time any remaining answer sheets should be handed in.
- The completed answer sheets will then be marked by the jury, who will apply time penalties as appropriate. The winning team will be announced at the closing ceremony.
- Everything you need will be provided on the table (calculator, office supplies, geometrical instruments, paper, table of constants).
- For one of the tasks, all the screens in the room will simultaneously display a video at a specified time (the video will be repeated several times).

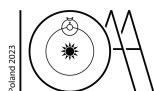


Table of Constants

Fundamental constants

Speed of light in vacuum	c	=	$2.998 \times 10^8 \text{ m s}^{-1}$
Planck constant	h	=	$6.626 \times 10^{-34} \text{ J s}$
Boltzmann constant	k_B	=	$1.381 \times 10^{-23} \text{ J K}^{-1}$
Stefan-Boltzmann constant	σ	=	$5.670 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$
Elementary charge	e	=	$1.602 \times 10^{-19} \text{ C}$
Universal gravitational constant	G	=	$6.674 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
Universal electric constant	ϵ_0	=	$8.854 \times 10^{-12} \text{ m}^{-3} \text{ kg}^{-1} \text{ s}^4 \text{ A}^2$
Universal gas constant	R	=	$8.315 \text{ J mol}^{-1} \text{ K}^{-1}$
Avogadro constant	N_A	=	$6.022 \times 10^{23} \text{ mol}^{-1}$
Wien's displacement constant	$b = \lambda_m T$	=	$2.898 \times 10^{-3} \text{ m K}$
Mass of electron	m_e	=	$9.109 \times 10^{-31} \text{ kg}$
Mass of proton	m_p	=	$1.673 \times 10^{-27} \text{ kg}$
Mass of neutron	m_n	=	$1.675 \times 10^{-27} \text{ kg}$
Mass of Helium nucleus	m_{He}	=	$6.645 \times 10^{-27} \text{ kg}$
Atomic mass unit (a.m.u., Dalton)		=	$1.661 \times 10^{-27} \text{ kg}$

Astronomical data

Hubble constant	H_0	=	$70 \text{ km s}^{-1} \text{ Mpc}^{-1}$
North Ecliptic Pole ($J2000.0$)	(α_E, δ_E)		$(18^{\text{h}}00^{\text{m}}00^{\text{s}}, +66^{\circ}33'39'')$
North Galactic Pole ($J2000.0$)	(α_G, δ_G)		$(12^{\text{h}}51^{\text{m}}26^{\text{s}}, +27^{\circ}07'42'')$
1 jansky	1 Jy	=	$10^{-26} \text{ W m}^{-2} \text{ Hz}^{-1}$
1 parsec	1 pc	=	$3.086 \times 10^{16} \text{ m}$ $206\,265 \text{ au}$ 3.262 ly
1 astronomical unit (au)	1 au	=	$1.496 \times 10^{11} \text{ m}$
1 sidereal day	T_{SD}	=	23.93444 h $23^{\text{h}}56^{\text{m}}04^{\text{s}}$
1 tropical year		=	$365.2422 \text{ solar days}$
1 sidereal year		=	$365.2564 \text{ solar days}$



Approximations

$$(1+x)^n \approx 1+nx$$

$$(1+x)(1+y) \approx 1+x+y \text{ if } x \ll 1 \text{ and } y \ll 1$$

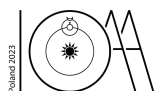
Gauss's formulae

Spherical law of cosines: $\cos a = \cos b \cos c + \sin b \sin c \cos A$

Spherical law of sines: $\frac{\sin A}{\sin a} = \frac{\sin B}{\sin b} = \frac{\sin C}{\sin c}$

next page $\Rightarrow$

Group Competition



UKR-S1 G-0 C-3

C0-3

English (Official)

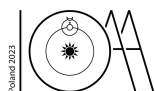
The Sun

Solar luminosity	$L_{\odot}$	=	$3.826 \times 10^{26} \text{ W}$
Apparent angular diameter of Sun	$\theta_{\odot}$	=	$32'$
Effective temperature of Sun	$T_{\text{eff},\odot}$	=	5778 K
Apparent visual magnitude		=	-26.75
Absolute visual magnitude		=	$+4.82$
Apparent bolometric magnitude		=	-26.83
Absolute bolometric magnitude		=	$+4.74$
Distance of the Sun from the Galactic centre		$\approx$	8 kpc

The Earth and Moon

Obliquity of the ecliptic (Earth)	ϵ	=	$23.5'$
Platonic year (period of precession of Earth's axis)		=	$25\,765 \text{ years}$
Apparent visual magnitude of full Moon		=	-12.74
Apparent angular diameter of Moon	θ_L	=	$31'$
Inclination of the lunar orbit to the ecliptic		=	$05^{\circ}08'43''$
Inclination of the lunar equator to its orbital plane		=	6.687°
Lunar sidereal month	T_{SL}	=	27.321661 d 655.71986 h
Synodic month		=	29.530589 d
Tropical month		=	27.321582 d
Anomalistic month		=	27.554550 d
Draconic month		=	27.212221 d

Group Competition



UKR-S1 G-0 C-4

C0-4

English (Official)

The Solar System

Object	Mean radius [km]	Mass [kg]	Semimajor axis [au]	Eccentricity
Sun	695 700	1.988×10^{30}	—	—
Mercury	2 440	3.301×10^{23}	0.387	0.206
Venus	6 052	4.867×10^{24}	0.723	0.007
Earth	6 378	5.972×10^{24}	1.000	0.016 710
Moon	1 737	7.346×10^{22}	3.844×10^5 km	0.054 900 (range 0.026 – 0.077)
Mars	3 390	6.417×10^{23}	1.524	0.093
Jupiter	69 911	1.898×10^{27}	5.203	0.048
Saturn	58 232	5.683×10^{26}	9.537	0.054
Uranus	25 362	8.681×10^{25}	19.189	0.047
Neptune	24 622	1.024×10^{26}	30.070	0.009



Question 1: Crossword

For each row of the table in the answer sheet, write in the three-letter IAU abbreviation of the constellation corresponding to the symbol. Your final answer is formed by the vertical column outlined in bold.

Hint: Mercator-projection sky map of constellations marked with symbols, below.

Penalties: empty space or wrong constellation: +1 minute

DELEGATION PRINT

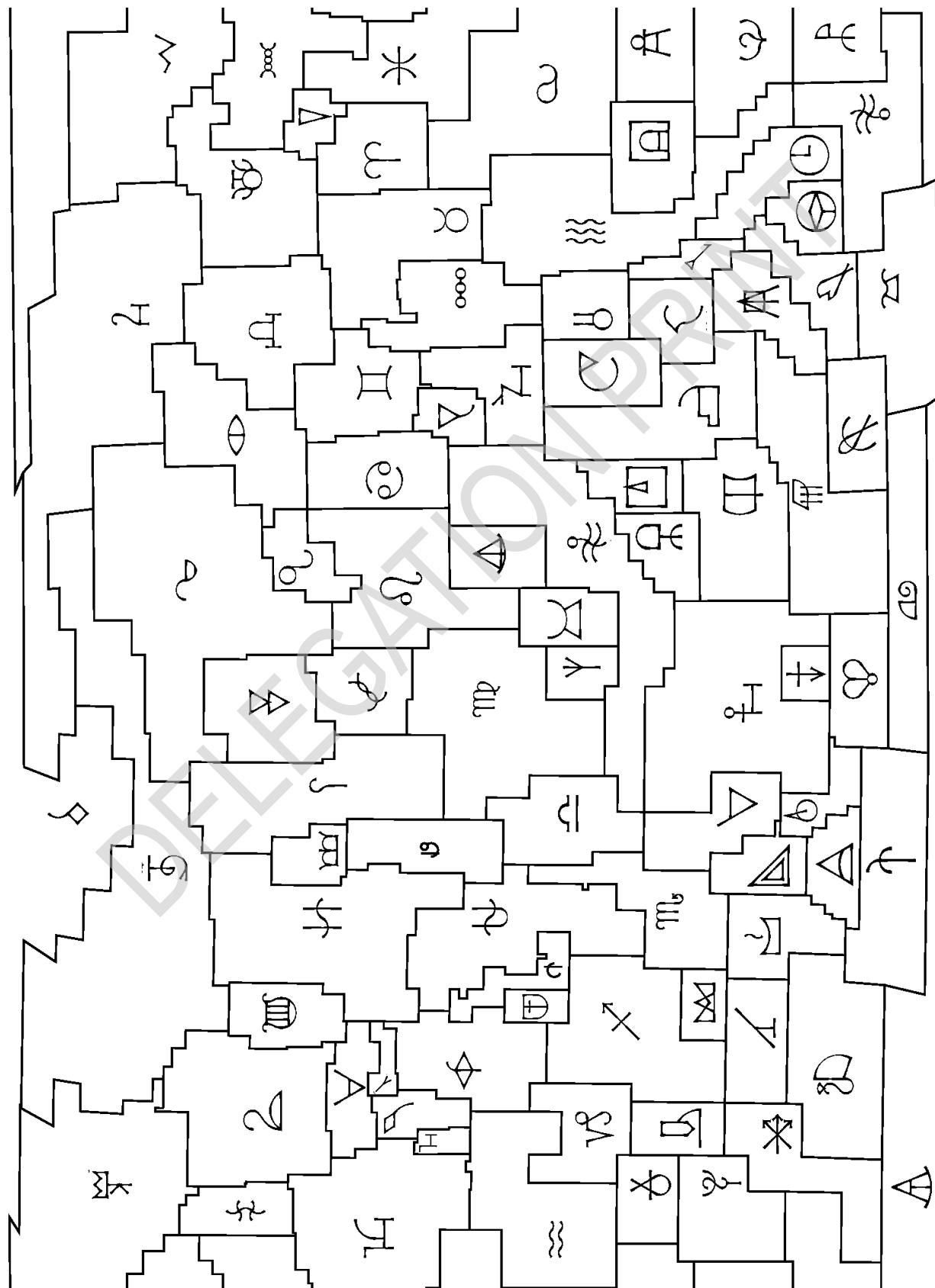
Group Competition



UKR-S1 G-1 Q-2

Q1-2

English (Official)





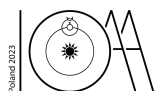
Question 2: Reply to Arecibo Message

During IOAA 2023, a reply to the message sent by the Arecibo radio telescope in 1974 finally reached Earth. A video recording of the transmission will be played on the monitors during the round. Decode the transmission and write the hidden message on the answer sheet.

The recording will begin playing 30 minutes after the start of the competition, and play continuously in a loop for a total of 30 minutes.

Penalties: missing or incorrect answer: +15 minutes

DELEGATION PRINT

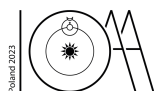


Question 3: Mars loop

- (a) On the provided graph paper, plot the X and Y positions of Earth and Mars in the heliocentric system over time using the data from the table, and draw vectors connecting the corresponding positions of Earth and Mars on each day.
- (b) Using a ruler and set square, translate each vector to a common origin while preserving their lengths and directions. Connect the ends of the translated vectors with a curve representing the position of Mars in the geocentric system.
- (c) From the plot, read off the minimal Earth–Mars distance, the duration of retrograde motion and the angle by which Mars moves backwards. Give your answers on the answer sheet.

Penalties: missing or incorrect drawing for part (b) +10 minutes; missing or out of range answers: +5 minutes for each part.

Group Competition



UKR-S1 G-3 Q-2

Q3-2

English (Official)

Heliocentric Equatorial Positions				
	EARTH		MARS	
Date	X [au]	Y [au]	X [au]	Y [au]
2022 Sep 01	0.9375	−0.3431	1.3235	0.4704
2022 Sep 11	0.9846	−0.1928	1.2724	0.5972
2022 Sep 21	1.0033	−0.0370	1.2082	0.7178
2022 Oct 01	0.9928	0.1198	1.1320	0.8312
2022 Oct 11	0.9530	0.2731	1.0448	0.9366
2022 Oct 21	0.8850	0.4184	0.9477	1.0331
2022 Oct 31	0.7905	0.5512	0.8417	1.1200
2022 Nov 10	0.6722	0.6673	0.7282	1.1967
2022 Nov 20	0.5336	0.7631	0.6082	1.2630
2022 Nov 30	0.3785	0.8356	0.4830	1.3184
2022 Dec 10	0.2119	0.8824	0.3537	1.3628
2022 Dec 20	0.0387	0.9020	0.2216	1.3960
2022 Dec 30	−0.1357	0.8936	0.0877	1.4182
2023 Jan 09	−0.3058	0.8574	−0.0468	1.4294
2023 Jan 19	−0.4665	0.7947	−0.1810	1.4297
2023 Jan 29	−0.6128	0.7073	−0.3139	1.4194
2023 Feb 08	−0.7401	0.5981	−0.4445	1.3988
2023 Feb 18	−0.8447	0.4705	−0.5719	1.3682
2023 Feb 28	−0.9234	0.3284	−0.6954	1.3280
2023 Mar 10	−0.9740	0.1765	−0.8140	1.2787
2023 Mar 20	−0.9954	0.0191	−0.9272	1.2207
2023 Mar 30	−0.9868	−0.1387	−1.0341	1.1545
2023 Apr 09	−0.9491	−0.2925	−1.1342	1.0807
2023 Apr 19	−0.8835	−0.4377	−1.2268	0.9998
2023 Apr 29	−0.7920	−0.5702	−1.3115	0.9124

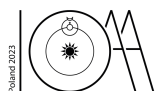


Question 4: Southern Pole Star

On the map of the southern sky in the answer sheet, draw the southern precession circle and determine the year, nearest to the present date, in which the star δ Velorum will become the southern pole star as a result of precession. The map is presented in the equidistant projection.

Penalties: missing or incorrect answer +10 minutes

DELEGATION PRINT



Question 5: Astrolabe

An astrolabe helps you determine the positions of selected stars relative to the horizon at a given time. The base, or 'mater', is marked with the horizon, curves of constant altitude, the pole, tropics, prime vertical and celestial equator (for latitude 50°N). The two movable transparent parts are the 'rete' and the 'rule'. The 'rete' shows the positions of certain stars, one from each constellation, as seen from outside the celestial sphere, as well as the ecliptic divided into the signs of the Zodiac. Finally the 'rule' is a scale which lets you determine the positions of stars in declination.

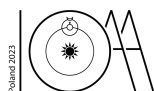
- (a) Identify the stars marked with letters on the rete and complete the table in the answer sheet. Give the name or Bayer designation and constellation, and the right ascension and declination (within ± 0.25 h and $\pm 5^\circ$). Mark the star which was the source of the alien transmission from Task 2.

Penalties: missing or incorrect names or incorrect coordinates: +1 minute each; wrong source star: +1 minute.

- (b) For the date of Nicolaus Copernicus's birthday (19 February) determine the right ascension and declination of the Sun (within ± 0.25 h and $\pm 5^\circ$), and the times of sunrise and sunset (within ± 0.25 h).

Penalties: missing or incorrect coordinates: +5 minutes; missing or incorrect times: +5 minutes.

Group Competition



UKR-S1 G-6 Q-1

Q6-1

English (Official)

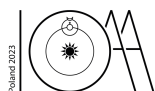
Question 6: Saros

Use the following table of lunar eclipses from the last 25 years to predict when the next lunar eclipse clearly visible from Poland (50°N, 19°E) will occur. Give the date and predicted hour on the answer sheet.

Penalties: for a missing answer +10 minutes, eclipse with weak visibility +1 minute

Date	Time UT	Type	JD
1991 Dec 21	10:34:00	Partial	2448602.940
1992 Jun 15	04:57:57	Partial	2448788.707
1992 Dec 09	23:45:05	Total	2448966.49
1993 Jun 04	13:01:26	Total	2449143.042
1993 Nov 29	06:27:06	Total	2449320.769
1994 May 25	03:31:20	Partial	2449497.647
1995 Apr 15	12:19:04	Partial	2449823.013
1996 Apr 04	00:10:47	Total	2450177.508
1996 Sep 27	02:55:24	Total	2450353.622
1997 Mar 24	04:40:28	Partial	2450531.694
1997 Sep 16	18:47:42	Total	2450708.283
1999 Jul 28	11:34:46	Partial	2451387.983
2000 Jan 21	04:44:34	Total	2451564.698
2000 Jul 16	13:56:39	Total	2451742.081
2001 Jan 09	20:21:40	Total	2451919.349
2001 Jul 05	14:56:23	Partial	2452096.115
2003 May 16	03:41:13	Total	2452775.653
2003 Nov 09	01:19:38	Total	2452952.556
2004 May 04	20:31:17	Total	2453130.345
2004 Oct 28	03:05:11	Total	2453306.628
2005 Oct 17	12:04:27	Partial	2453661.003
2006 Sep 07	18:52:25	Partial	2453986.286
2007 Mar 03	23:21:59	Total	2454163.474
2007 Aug 28	10:38:27	Total	2454340.943
2008 Feb 21	03:27:09	Total	2454517.644
2008 Aug 16	21:11:12	Partial	2454695.383
2009 Dec 31	19:23:46	Partial	2455197.308
2010 Jun 26	11:39:34	Partial	2455373.986
2010 Dec 21	08:18:04	Total	2455551.846
2011 Jun 15	20:13:43	Total	2455728.343

Group Competition



UKR-S1 G-6 Q-2

Q6-2

English (Official)

Date	Time UT	Type	JD
2011 Dec 10	14:32:56	Total	2455906.106
2012 Jun 04	11:04:20	Partial	2456082.961
2013 Apr 25	20:08:38	Partial	2456408.34
2014 Apr 15	07:46:48	Total	2456762.824
2014 Oct 08	10:55:44	Total	2456938.956
2015 Apr 04	12:01:24	Total	2457117.001
2015 Sep 28	02:48:17	Total	2457293.617
2017 Aug 07	18:21:38	Partial	2457983.265
2018 Jan 31	13:31:00	Total	2458150.063
2018 Jul 27	20:22:54	Total	2458327.349
2019 Jan 21	05:13:27	Total	2458504.717
2019 Jul 16	21:31:55	Partial	2458681.397
2021 May 26	11:19:53	Total	2459360.972
2021 Nov 19	09:04:06	Partial	2459537.878
2022 May 16	04:12:42	Total	2459715.676
2022 Nov 08	11:00:22	Total	2459891.958