International Olympiad on Astronomy and Astrophysics

Theoretical Problems

(Short Questions)

8th International Olympiad on Astronomy and Astrophysics

Suceava - Gura Humorului - August 2014

Instructions

1. In your folder you will find the following items:
   a. Answer sheets
   b. Rough work sheets
   c. The envelope with the problems The solutions of the problems should be written only on the answer sheets you receive. **PLEASE WRITE ONLY ON THE PRINTED SIDE OF THE PAPER SHEET. DON'T USE THE REVERSE SIDE**. The evaluator will not take into account what is written on the reverse side of the answer sheet.
2. The rough worksheets are for your own use for doing calculations, write some numbers etc. BEWARE: These sheets are not taken into account for the evaluation. At the end of the test they will be collected separately. Everything you consider as part of the solutions should be written on the answer sheets.
3. Each problem should be started on a separate answer sheet.
4. On each answer sheet please fill in the designated boxes as follows:
   a. In the „PROBLEM NO." box write down only the number of the problem: i.e. 1 – 12 for each short problems, 13 – 15 for each long problems. Each sheet containing the solutions of a certain problem, should have in the box the number of the problem;
   b. In „Student ID" – fill in your ID that you will find on your envelope, consisting of 3 leters and 2 digits.
   c. In the „page no." box you will fill in the number of page, starting from 1. We advise you to fill this boxes after you finish the test
5. We don't understand your language, but the language of Mathematics is universal, so, please, use as many mathematical expressions as you think that may help the evaluator to better understand your solutions. If you want to explain something in words we kindly ask you to use short phrases(if possible in English).
6. Use the pen you find out on the desk. It is advisable to use a pencil for the sketches.
7. At the end of the test:
   d. Don't forget to put your papers in order.
   e. Put the answer sheets in folder 1. Please verify that all the pages contain your ID, correct numbering of the problems and all pages are in the right order and numbered. This will help us to understanding your solutions.
   f. Verify with the assistant the correct number of answer sheets used and fill in this number on the cover of the folder and sign it.
   g. Put the draft papers in the designated folder. Put the test papers back in the envelope.
   h. Go to swim

GOOD LUCK !

Problem 1. Lagrange Points

The *Lagrange* points are the five positions in an orbital configuration (assume circular orbits), where a small object is stationary relative to two big bodies, only gravitationally interacting with them- for example, an artificial satellite relative to Earth and Moon, or relative to Earth and Sun. In the **Figure 1** are sketched two possible locations of Lagrange points L_3 relative to relative to the Earth – Sun system . Find out which of the two locations L_3^1 and L_3^2 could be the real Lagrange point relative to the system Earth – Sun; show the reason for your

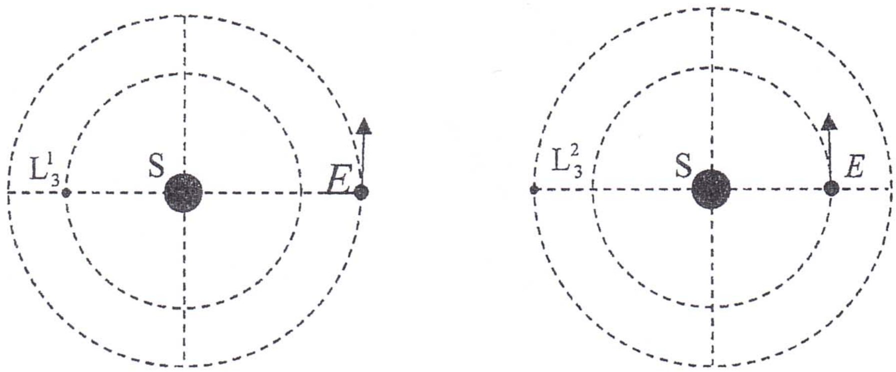


Figure 1A **Figure 1B**

answer with appropriate equations and calculate the difference between one AU and Sun - L_3 distance . You know the following data: the Earth - Sun distance $d_{ES} = 14.96 \cdot 10^7$ km and the Earth – Sun mass ratio $M_E / M_S = 1/332946$

Problem 2. Sun gravitational catastrophe!

In a gravitational catastrophe, the mass of the Sun mass decrease instantly to half of its actual value. If you consider that the actual Earth orbit is elliptical, its orbital period is $T_0 = 1\ year$ and the eccentricity of the Earth orbit is $e_0 = 0.0167$.

Find the period of the Earth`s orbital motion, after the gravitational catastrophe, if it occurs on: a) 3rd of July (aphelion) b) 3rd of January.

Problem 3. Cosmic radiation

During studies concerning cosmic radiation, a neutral unstable particle – the π^0 meson was identified. The rest-mass of meson π^0 is much larger than the rest-mass of the electron. The studies reveal that during its flight, the meson π^0 disintegrates into 2 photons. In a particular case, one of the created photons has the maximum possible energy E_{max} and, consequently, the other one has the minimum possible energy E_{min}.

Find an expression for the initial velocity of the meson π^0, as a function of E_{max} and E_{min}. You may use as known **c** - the speed of light and the relation between the energy and momentum of any relativistic particles $E^2 = p^2c^2 + m_0^2c^4$

Problem 4. Sandra Bullock And George Cloony

An astronaut, with mass $M = 100$ kg, gets out of the space ship for a repairing mission. He has to repair a satellite at rest relative to the space ship, at about $d = 90\,\text{m}$ away from it. After he finishes his job, he realizes that the systems designed to assure his come-back to shuttle are broken. He also observes that he has air only for 3 minutes. He also notices that he possessed a sealed cylindrical can (base section $S = 30\ \text{cm}^2$) firmly attached to his/her glove, with $m = 200$ g of ice inside. The can is not completely filled with ice.

Determine if the astronaut is able to return safely to the shuttle, before his air reserve is empty, if he manages to open the can in correct direction. Briefly explain your calculations. Note that he cannot throw away anything of its equipment, or touch the satellite.

You may use the following data: $T = 272\,\text{K}$ / the temperature of the ice in the can, $p_s = 550\,\text{Pa}$ - the pressure of the saturated water vapors at the temperature $T = 272\,\text{K}$; $R = 8300\ \text{J/(kmol·K)}$ - the universal gas constant; $\mu = 18\ \text{kg/kmol}$ - the molar mass of the water.

Problem 5. The life –time of a main sequence star

The plot of the function $\log(L/L_S) = f(\log(M/M_S))$ for data collected from a number of stars is represented in figure 2. L and M are the luminosity and the mass of a star respectively and L_S and M_S the luminosity and the mass of the Sun respectively.

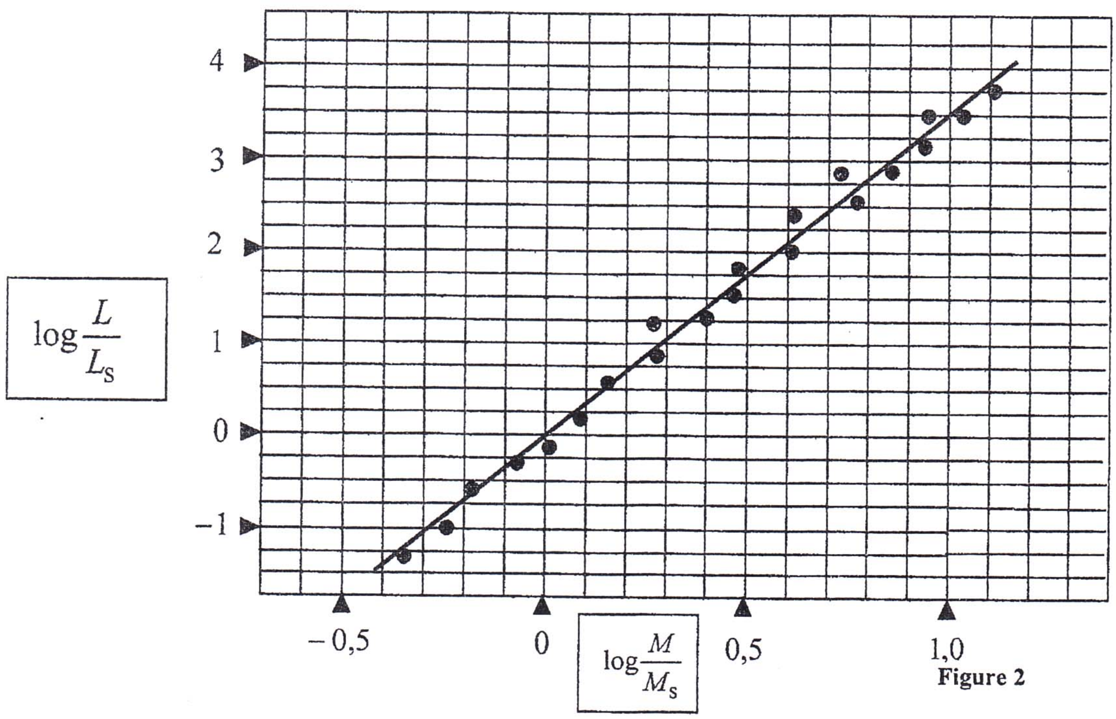


Figure 2

Find an expression for the main sequence life- time for a main sequence star from Hertzprung – Russell diagram, as a function of mass fraction converted to energy η and mass ratio to the solar mass γ , Use the following assumptions: the time spent by Sun in the same Main Sequence is τ_S , for each star the mass fraction which changed into energy is η , the percent of the mass of Sun which changes into energy is η_S , the mass of each star is expressed as $\gamma = \frac{M}{M_S}$ and assume that luminosity of the star remains constant, during its main sequence life time.

Problem 6. The effective temperature on the surface of a star

From the radiation emitted by a star, two radiations with wavelength values in a narrow range $\Delta\lambda << \lambda$ are studied, i.e. the wavelength have values between λ and $\lambda + \Delta\lambda$. According to Planck's relationship (for an absolute black body), the following relation defines, the energy emitted by star in unit time, through a unit area of its surface, per unit wavelength interval:

$$r = \frac{2\pi hc^2}{\lambda^5\left(e^{\frac{hc}{k\lambda T}} - 1\right)}.$$

The spectral intensities of the radiation with wavelengths λ_1 and respectively λ_2, both within the range $\Delta\lambda$ measured on Earth are $I_1(\lambda_1)$ and $I_2(\lambda_2)$ respectively.

Find out the relation between wavelength λ_1 and λ_2, if $I_1(\lambda_1) = 2I_2(\lambda_2)$, when $hc << \lambda kT$.

Here: h – Planck's constant; k – Boltzmann's constant; c – speed of light in vacuum. $e^x \approx 1 + x$ if $x << 1$

✓ **Problem 7. Pressure of light**

For an observer on Earth the pressure of the radiation emitted by Sun is $p_{rad,S}$ and the pressure of the radiations emitted by a star Σ is $p_{rad,\Sigma}$.

Calculate the visual apparent magnitude of the star Σ if the apparent visual magnitude of the Sun is m_S. The following assumption may be useful for solving the problem:

Generally, the pressure of the electromagnetic radiation in vacuum is equal to the volume energy density of the electromagnetic radiation $\left(p_{\text{rad}} = \dfrac{\Delta E}{\Delta V}\right)$.

The following data are known: M_S - the mass of the Sun, R_S - the radius of Sun, G - universal gravitational constant; σ Stefan - Boltzmann's constant ; c – speed of light in vacuum

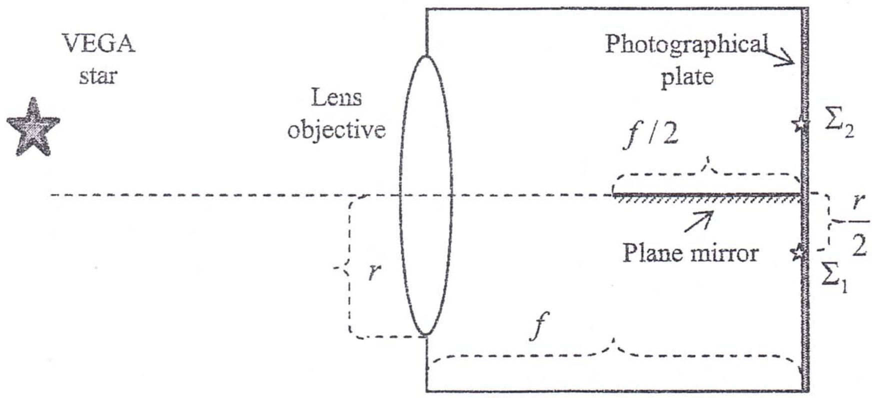
Problem 8. Space – ship orbiting the Sun

A spherical space –ship orbits the Sun on a circular orbit, and spin around an axis of rotation that is perpendicular to the orbital plane of the space-ship. The temperature on the exterior surface of the ship is T_N. Assume the space -ship is a perfect black body and there is no activity inside it .

Find out the apparent magnitude of the Sun and the angular diameter of the Sun as seen by the astronaut on board of the space – ship. The following values are known:, T_S - the effective temperature of the Sun; R_S - the radius of the Sun; d_0 - the Earth –Sun distance; m_0 - apparent magnitude of Sun measured from Earth; R_N - the radius of the space –ship.

Problem 9. The Vega star in the mirror

Inside a camera a plane mirror is placed along the optical axis of the objective (as shown in figure). The length of the mirror is half the focal length of the objective. A photographic plate is placed at the focal plane of the camera. Two images with different brightness are captured on the photographic plate (as shown in figure). The star Vega is not on the optical axis of the lens. The distance between the optical axis and the image Σ_1 is $\frac{r}{2}$.Find the difference between the apparent photographical magnitudes of the two images of the star Vega.



Figure

Problem 10. Stars with Romanian names

Two Romanian astronomers Ovidiu Tercu and Alex Dumitriu from Galati Romania, recently discovered two variable stars. The galactic coordinates of the two stars are: Galati V1 $(l_1 = 114.371^\circ; b_1 = -11.35^\circ)$ and Galati V2 $(l_2 = 113.266^\circ; b_2 = -16.177^\circ)$.

Estimate the angular distance between the stars Galati V1 and Galati V2

Problem 11. Apparent magnitude of the Moon

The apparent magnitude of the Moon as seen from the Sun is $M_M = 0.25^m$

Calculate the values of the apparent magnitudes of the Moon (as seen from the Earth) corresponding to the following Moon – phases : full-moon and the first quarter. Assume: the Moon – Earth distance - $d_{ME} = 385000\,\text{km}$, the Earth – Sun distance - $d_{ES} = 1\,AU$, the Moon –Sun distance, $d_{MS} = 1\,AU$. For terrestrial observers, following phase factor must be used to correct the lunar brightness for curvature of lunar surface and phase of the moon.

$$p(\Psi) = \frac{2}{3}\cdot\left[\left(1-\frac{\Psi}{\pi}\right)\cos\Psi + \frac{1}{\pi}\sin\Psi\right],$$ where Ψ is the phase angle.

Problem 12. Absolute magnitude of a cepheid

The cepheids are variable stars, whose luminosities vary due to stellar pulsations. The period of the oscillations of a cepheid star is:

$$P = 2\pi R\sqrt{\frac{R}{GM}},$$

where: R – the mean radius of the cepheid; M – the mass of the cepheid (remains constant during oscillation), you can assume that the temperature is constant during the pulsation;

Express the mean absolute magnitude of the cepheid M_{cep}, in the following form:

$$M_{cef} = -2{,}5^m \cdot \log k - \left(\frac{10}{3}\right)^m \cdot \log P,$$

where P is the period of cepheid's pulsation.

International Olympiad on Astronomy and Astrophysics

Theoretical Problems

(Long Questions)

13. Long problem 1. Eagles on the Caraiman Cross !

The tallest cross built on a mountain peak is located on a plateau situated on the top of the peak called Caraiman in Romania at altitude $H = 2300\,m$ from the sea level. Its height, including the base-support is $h = 39{,}3\,m$. The horizontal arms of the cross are oriented on the N-S direction. The latitude at which the Cross is located is $\varphi = 45^\circ$.

A. On the evening of 21st of March 2014, the vernal equinox day, two eagles stop from their flight, first near the monument, and the second, on the top of the Cross as seen in figure 1. The two eagles are in the same vertical direction. The sky was very clear, so the eagles could see the horizon and observe the Sun set. Each eagle began to fly right at the moment it observed that the Sun disappeared completely.

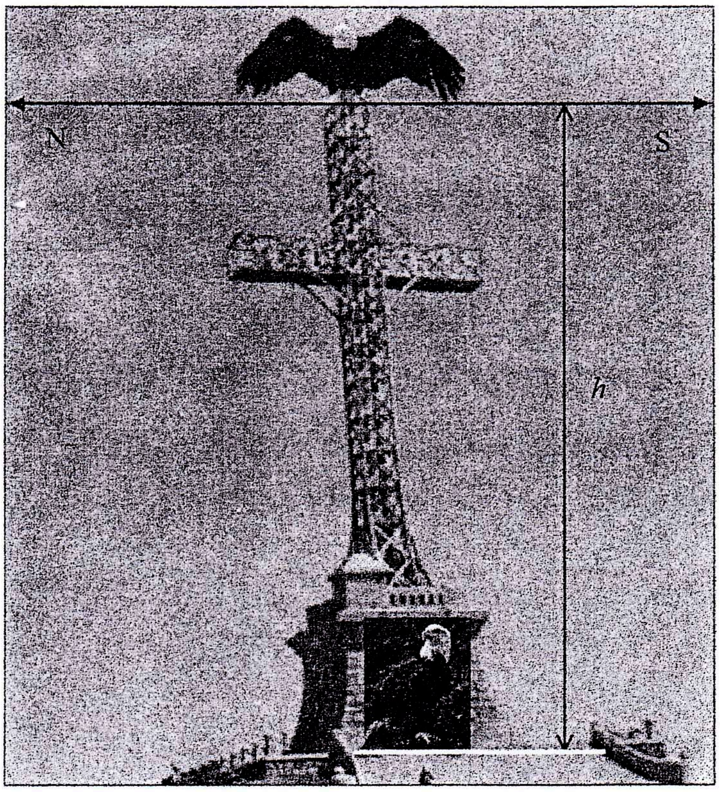


Figure 1

At the same time, an astronomer is located at the sea-level, at the base of the Bucegi Mountains. Assume that he is in the same vertical direction as the two eagles.

Assuming the atmospheric refraction to be negligible, solve the following questions:

1) *Calculate* the duration of the sunset, measured by the astronomer.

2) *Calculate* the durations of sunsets measured by each of the two eagles and indicate which of the eagles leaves the Cross first. What is the time interval between the moments of the flights of the two eagles.

The following information is necessary:

The duration of the sunset measurement starts when the solar disc is tangent to the horizon line and stops when the solar disc completely disappears.

The Earth's rotational period is $T_E = 24\,\text{h}$, the radius of the Sun $R_S = 6{,}96 \cdot 10^5\ \text{km}$, Earth – Sun distance $d_{ES} = 14.96 \cdot 10^7\ \text{km}$, the latitude of the Heroes Cross is $\varphi = 45^\circ$. $R_E = 6370\,\text{km}$

B) At a certain moment the next day, 22nd March 2014, the two eagles come back to the Heroes Cross. One of the eagles lands on the top of the vertical pillar of the Cross and the other one land on the horizontal plateau, just at the tip of the shadow of the vertical pillar of the Cross, at that moment of the day when the shadow length is minimum.

1) Calculate the distance between the two eagles and the second eagle's distance from the cross.

2) Calculate the length of the horizontal arms of the Cross l_b, if the shadow on the plateau of one of the arm of the cross at this moment has the length $u_b = 7\ \text{m}$

C) At midnight, the astronomer visits the cross and, from its top, he identifies a bright star at the limit of the circumpolarity. He named this star „Eagles Star". Knowing that due to the atmospheric refraction the horizon lowering is $\xi = 34'$, calculate:

1) The "Eagles star" declination;

2) The "Eagles star" maximum height above the horizon.

14. Long problem 2. From Romania .... to Antipod! ...with a ballistic messenger

The 8th IOAA organizers plan to send to the **antipode** (the point on the Earth's surface diametrically opposite to the launch position) the official flag using a ballistic projectile. The projectile will be launched from Romania, and the rotation of the Earth will be neglected.

a) Calculate the coordinates of the target-point if the launch-point coordinates are: $\varphi_{\text{Romania}} = 44^\circ\ North;\ \lambda_{\text{Romania}} = 30^\circ\ \text{Est}$.

b) Determine the magnitude of the velocity and the launch angle, with respect to the horizon at launch site, in order that the projectile should hit the target.

c) Calculate the velocity of the projectile when it hits the target.

d) Calculate the minimum velocity of the projectile on its trajectory.

e) Calculate the flying –time of the projectile, from the launch to the impact. You may use the value of the gravitational acceleration at Earth surface as $g_0 = 9.81\,\mathrm{ms^{-2}}$; the Earth radius $R = 6370\,\mathrm{km}$.

f) Will it be possible that the projectile will be seen by the naked eye when it is at the maximum distance from the Earth. You will use the following values: The Moon albedo $\alpha_M = 0.12$; The Moon radius $R_M = 1738\,Km$; the Earth –Moon distance $r_{EM} = 385000$ km; the apparent magnitude of the full moon $m_M = -12.7^m$. You assume that the projectile is perfectly metallic sphere with radius $r_{projectile} = 400\,x\,10^{-3}\,m$ and with perfectly reflective surface.

International Olympiad on Astronomy and Astrophysics

Data Analysis Problems

Instructions

1) In your folder you will find out the following:
   a) Answer sheets
   b) Draft sheets
   c) The envelope with the subjects in English and the translated version of them in your mother tongue;
2) The solutions of the problems will be written down only on the answer sheets you receive on your desk. **PLEASE WRITE ONLY ON THE PRINTED SIDE OF THE PAPER SHEET. DON'T USE THE REVERSE SIDE**. The evaluator will not take into account what is written on the reverse of the answer sheet.
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5) On each answer sheet please fill in the designated boxes as follows:
   a) In PROBLEM NO. box write down only the number of the problem: i.e. 1 – 3. Each sheet containing the solutions of a certain problem, should have in the box the number of the problem;
   b) In Student ID – fill in your ID you will find on your envelope, consisted of 3 leters and 2 digits.
   c) In page no. box you will fill in the number of page, starting from 1. We advise you to fill this boxes after you finish the test
6) We don't understand your language, but the mathematic language is universal, so use as more relationships as you think that your solution will be better understand by the evaluator. If you want to explain in words we kindly ask you to use short English propositions.
7) Use the pen you find out on the desk. It is advisable to use a pencil for the sketches.
8) At the end of the test:
   a) Don't forget to put in order your papers;
   b) Put the answer sheets in the folder 1. Please verify that all the pages contain your ID, correct numbering of the problems and all pages are in the right order and numbered. This is an advantage of ease of understanding your solutions.
   c) Verify with the assistant the correct number of answer sheets used fill in this number on the cover of the folder and sign.
   d) Put the draft papers in the designated folder, Put the test papers back in the envelope.
   e) Go to swim

GOOD LUCK !

Problem 1 Black Hole in Milky Way

By observational facts, the scientists admit presence of a black-hole at the center of Milky Way.
At the center of Milky Way, a hypothetical black-hole (Sagittarius A*) is located. A star S* is orbiting the black-hole SA*.

In the table 1 the following data is presented: the date and the angular position coordinates $(\alpha;\beta)$ of the star S* at different moments of the observation. The coordinates represent the angular distances of the projection or the star S* in the coordinates system (U, W), centered on the SA* (see figure 1).

An angular distance of $\varphi = 1$ arcsec corresponds to linear distance in the plane of the sky $d = 41$ light days, therefore to a scale $S_0 = \frac{d}{\varphi} = 41 \frac{\text{light day}}{\text{arcsec}}$.

	Date (year)	α(arcsec)	β(arcsec)
1	1995.222	0.117	- 0.166
2	1997.526	0.097	- 0.189
3	1998.326	0.087	- 0.192
4	1999.041	0.077	- 0.193
5	2000.414	0.052	- 0.183
6	2001.169	0.036	- 0.167
7	2002.831	- 0.000	- 0.120
8	2003.584	- 0.016	- 0.083
9	2004.165	- 0.026	- 0.041
10	2004.585	- 0.017	0.008
11	2004.655	- 0.004	0.014
12	2004.734	0.008	0.017
13	2004.839	0.021	0.012
14	2004.936	0.037	0.009
15	2005.503	0.072	- 0.024
16	2006.041	0.088	- 0.050
17	2007.060	0.108	- 0.091

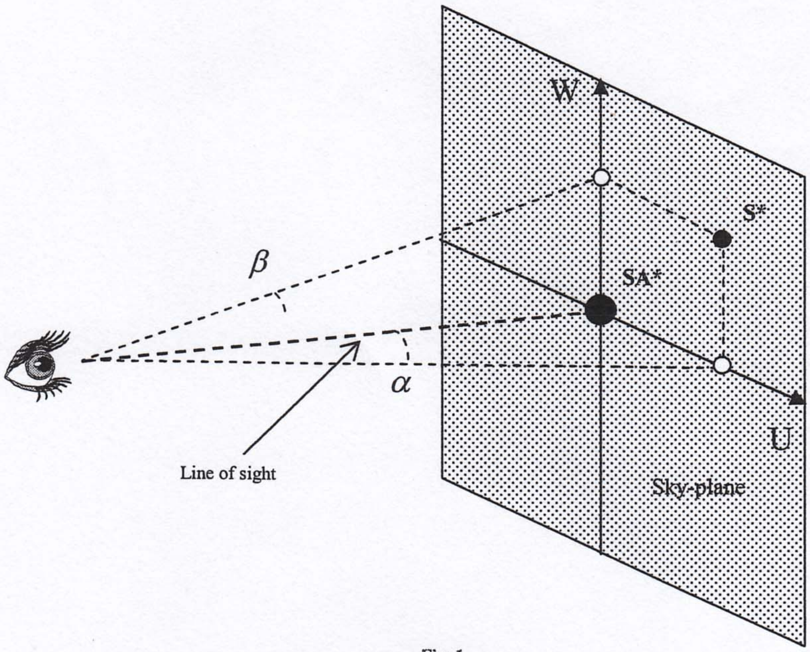


Fig. 1

By using the information provided your tasks are:

a) Plot the projection of the trajectory of the star S^* in the plane P (see figure 2). This plane is close to the observer. In this plane, $\varphi = 1$ arcsec corresponds to a linear distance d_0= 1200 mm therefore the scale is $S = \frac{d_0}{\varphi} = 1200 \frac{mm}{\text{arcsec}}$. You have to use the millimeter graph paper, carbon copy sheet of paper and the transparent sheets for an accurate plot.

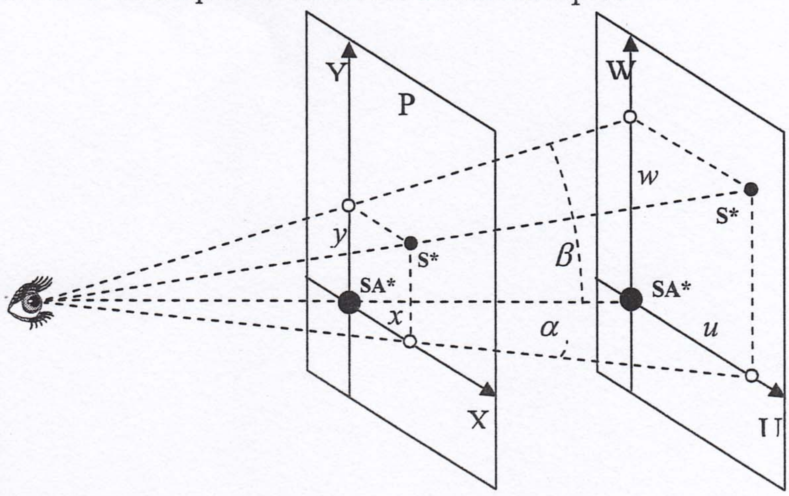


Fig. 2

b) By using the plot prove that the line of sight is normal to the actual plane of the orbit

c) Using your plot find out following elements of the real orbit of star S* around the black hole SA*:

I. $a-$semi-major axis (in light days units) ; $b-$small semi-minor axis in (in light days units); $e-$eccentricity;

II. $r_{\min}-$the minimum distance between S* and SA*(in light days units); $r_{\max}-$the maximum distance between S* and SA* (in light days units);

III. The distance from the observer to the S*;

IV. the orbiting period of star S* around SA* (obtain the best possible result by taking as many measurements as possible and by taking their arithmetic mean);

V. the total mass of the system "SA* - S*".

Presenting the intermediate and final data in tables is recommended for an accurate evaluation.

$G = 6.67 \cdot 10^{-11}\ \mathrm{Nm^2kg^{-2}}$

Problem 2Thermodynamic test

An hypotetical shuttle is launched to investigate the atmosphere (100% CO_2)of two extrasolar planets P_1 and P_2. The atmosphere is in static thermodynamic equilibrium. When the shuttle is near each planet, a radio probe is launched toward respective planet, invertical direction (in the direction of the planet`sradius). When the radio probe reaches constant velocity, it starts sending values of the pressure of the atmosphere. In Fig. 3.1 is plotted the atmospheric pressure values (in arbitrary units) as function of the time of descent for the planet P_1. When the probe touches the surface of planet P_1 it sends the value of the temperature $T_0 = 700$ K and the value of the gravitational acceleration $g_0 = 10\ \mathrm{ms^{-2}}$.

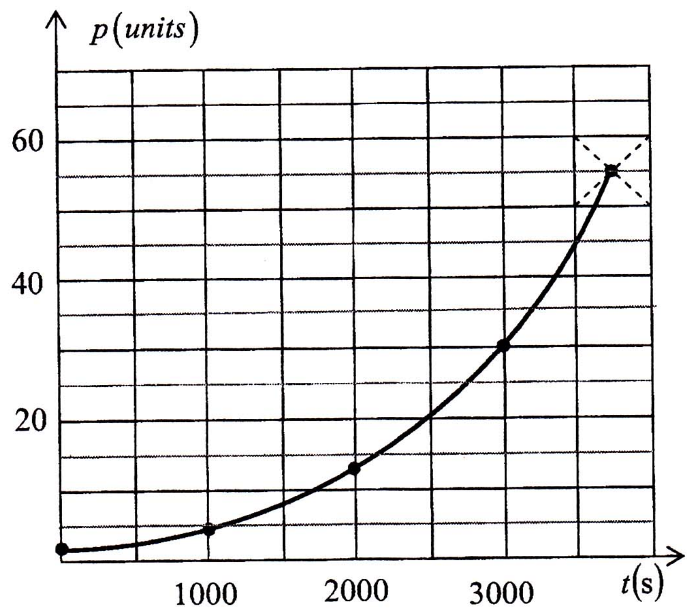


Fig. 3.1.

The gravitational acceleration on each planet is assumed to be constant during uniform descent of the radio probes.

a) Find the altitude h_0 from where the radio probe R_1 starts the uniform descent and thus starts the transmitting information.

b) Find the temperature of planet P_1 at the altitude $h = 39.6\,\text{km}$. You know: The universal gas constant $R = 8.3\ \text{J/molK}$; the molar mass of CO_2, $\mu = 44\ \text{g/mol}$.

c) In Fig. 3.2.was plotted the atmospheric pressure values (in arbitrary units) as a function of time of descent forthe planet P_2atmosphere. When the probe touched the surface of the planet P_2, it sends the value of the temperature $T_0 = 750\ \text{K}$ and respectively the value of gravitational acceleration $g_0 = 8\ \text{ms}^{-2}$

Draw the following dependency graphs for $p = f(h)$ and $T = f(h)$ in the CO_2 atmosphere of the planet P_2.

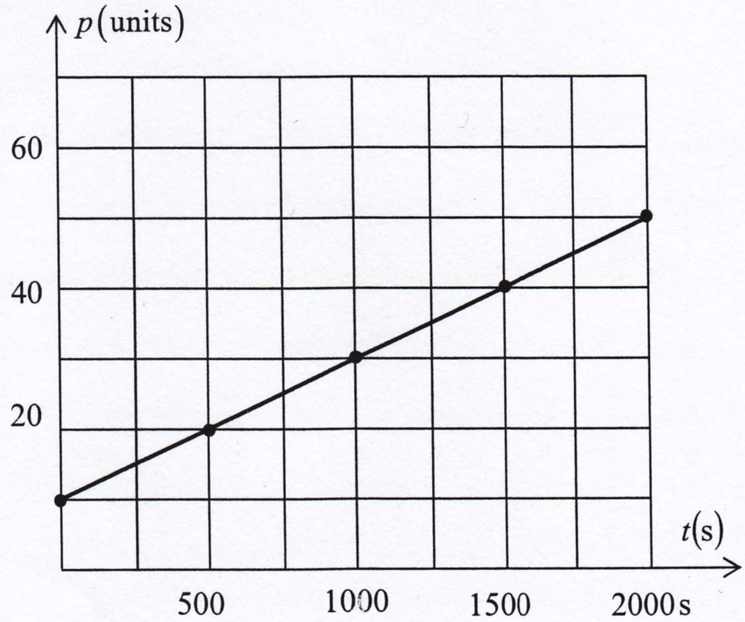


Fig. 3.2.

Problem 3 IOAA Observer on an extrasolar planet

The Sirius star, located in the constellation ofCanis Major, is the brightest star in the night sky of the Earth. What the observer's eye sees as a single star is actually a binary star system.

The high brightness of Sirius is a consequence of two facts: its intrinsic luminosity and its proximity to the Earth.

The Mizar multiple star system, in the constellation of Ursa Major, consists of 4 stars seen along the same line of sight from the Earth. Some of these stars form a gravitationally bound system.

Let's assume that an observer (observer A) is located on one of the planets of the Sirius system.

Determine:

a) The magnitude of the Sun as seen by observer A($m_{\text{Sun,Planet}}$).

b) The magnitude of Sirius star system as seen by the observer A.($m_{SY,\text{Planet}}$)

c) Thecombined intrinsic luminosity of theMizarsystem , L_{Mizar};

d) the average distance between gravitationally bound stars of the Mizar system and Earth,

e) The geocentric angular distancebetweenMizarsystemand Sirius, $\Delta\theta$;

f) The physical distance between the gravitationally bound stars of theMizar system and the observer A. ($d_{\text{Mizar,Planet}}$)

g) The magnitude of the entire Mizar system as seen by the observer A.($m_{\text{Mizar,Planet}}$)

Also estimate amount of errorsin all your answers.

The following data may be used:

$d_{\text{Sirius},Earth} = 2.6\text{ pc}$ - the Sirius – Earth distance;

$m_{\text{Sirius},Earth} = -1.46^{\text{m}}$ - the apparent magnitude of Sirius measured from the Earth;

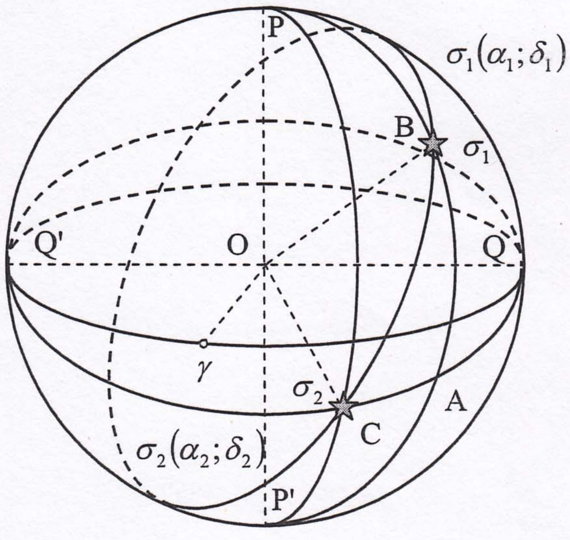
$d_{Sun,Earth} = 1\text{ AU}$ - theSun – Earth distance;

$m_{\text{S}un,Earth} = -26{,}78^{\text{m}}$ - the apparent magnitude of the Sun as seen from Earth ;

$d_{\text{Sirius, Planet}} = 10\text{ AU}$ - distance between Sirius and its planet where the observer A is located;

In the table below information for the stars from the Mizar system as measured from the Earth is given.

Star number	Name of the star	Apparent magnitude	Parallax (mili arc seconds)
1	Alcor	3.99 ± 0.01	39.91 ± 0.13
2	Mizar A	2.23 ± 0.01	38.01 ± 1.71
3	Mizar B	3.86 ± 0.01	38.01 ± 1.71
4	Sidus Ludoviciana	7.56 ± 0.01	8 ± 4



The equatorial coordinates of Mizar system (σ_1) and respectively of Sirius (σ_2) , located on the heliocentric map are :

$\alpha_{Mizar} = \alpha_1 = 13^{\text{h}}23^{\text{min}}55.5^{\text{s}}$;

$\delta_{Mizar} = \delta_1 = 54^\circ 55' 31''$; $\alpha_{\text{Sirius}} = \alpha_2 = 6^{\text{h}}45^{\text{min}}$;

$\delta_{\text{Sirius}} = \delta_2 = -16^\circ 43'$.

Note

$\ln(1-x) \approx -x$ for $x << 1$

$e^x \approx 1 + x$ for $x << 1$

International Olympiad on Astronomy and Astrophysics

Observational Problems

(Planetarium Round)

OBSERVATIONAL
TEST
PLANETARIUM

PART I
READ CAREFULY

Inside the dome:

1) The observational round in the planetarium consists of two parts, one inside the dome and the other outside the dome.
2) The inside part consists of 3 questions and takes 30 minutes.
3) When you enter the dome, you will be directed to your seat. Here you will find a clipboard with your answer sheet attached, one data table and a flashlight. During the adaptation time the students may stand and change the position around his place, but they are not allowed to communicate with each other. During the observation you can stand and turn in order to make a comfortable observation.
4) Fill your student ID in the box on the answersheet.
5) PAY ATTENTION TO THE ASSISTANTS, and follow their instructions.
6) The timing for the first part is as follows:
   a) **8 minutes for your eye adaptation to the darkness;**
   b) **10 minutes for the first question;**
   c) **6 minutes for the second question;**
   d) **6 minutes for the third question;**
7) Use the flash light only when you need it and point it only to your paper.
8) When you leave the dome, leave everything on your seat.

9) PLEASE WRITE ONLY ON THE PRINTED SIDE OF THE ANSWER SHEET. DON'T USE THE REVERSE SIDE. The evaluator will not take into account what is written on the reverse of the answer sheet.

GOOD LUCK!

OBSERVATIONAL PLANETARIUM

PART I
Answer sheet

STUDENT ID	

Please write ONLY on this side of the paper

Question 1

The sky projected in the dome corresponds to Suceava (Long 26^0 15'), at 18:00 UT, on a certain day of a certain month.

8 minutes – relax and familiarize your eyes with the darkness. During this time don't use the flash light.

Two arcs of circle will now be projected. The arcs are segmented. Each segment represents an interval of some degrees. This number is not the same for each arc.

10 minutes – **Question 1**

a. Identify each arc by circling the correct name and give the angular size of each segment (in degrees).

First arc	**Equator**	**Meridian**	**Ecliptic**	**Segment size**
Second arc	**Equator**	**Meridian**	**Ecliptic**	**Segment size**

b. Estimate the local sidereal time of the sky you see in the dome.

$\theta_{sidereal}$	

c. Determine the month to which the projected sky would correspond at the given time. Fill in the box the number of the month (1 to 12).

Month number	

OBSERVATIONAL PLANETARIUM	PART I / Answer sheet	STUDENT ID	

Please write ONLY on this side of the paper

Question 2 and 3

For questions 2 and 3 the assistant will use a small red arrow pointer to point some objects in the sky. Each object will be pointed at for **2 minutes** (30 seconds arrow pointer on and 10 seconds off)**.** Please pay attention to the assistant announcements.

6 minutes – Question 2

Location of three Messier objects will be pointed one by one. For each Messier object pointed, fill in the boxes the Messier catalog number of it and the number which indicates its type, as follows: **1 for galaxy, 2 for nebula, 3 for open cluster, 4 for globular cluster.**

Also, for each object, fill in the appropriate box the IAU abbreviation of the constellation where the star is located. Use **Table 1** for this purpose.

1st Messier object		Number which indicates the type		IAU abbreviation of the constellation	
2nd Messier object		Number which indicates the type		IAU abbreviation of the constellation	
3rd Messier object		Number which indicates the type		IAU abbreviation of the constellation	

6 minutes – Question 3

Three stars will be pointed successively. Each star will be pointed 2 minutes. Fill the appropriate box the name of the star (or Bayer designation) and the number which indicates its type (**1 for single, 2 double**). Also, for each star, fill in the appropriate box the IAU abbreviation of the constellation where the star is located. Use for that **Table 1**.

1st Star		Number which indicates the type		IAU abbreviation of the constellation	
2nd Star		Number which indicates the type		IAU abbreviation of the constellation	
3rd Star		Number which indicates the type		IAU abbreviation of the constellation	

You have finished the first part. Verify if you have written your student ID on every page. Put the clipboard with the answer sheets attached and the flashlight on your seat, and leave the dome.

MARKING SCHEME for Observational_part1 – Planetarium (50 points)

Question1 (20 points)

a. First arc length – length **– MERIDIAN 10º - 1p+2p**
Second arc segment length **– EQUATOR 15º - 1p+2p**

b. $\theta_{sidereal}$ – **13h30m** **6p**
+/- 15 m – full points; +/- 30 m half points

c. Month number – **June (6) - 8p**

Question 2 (15 points)

1st Messier object	M101 **2p**	Number which indicates the type	1 **1p**	IAU abbreviation of the constellation	UMa **2p**
2nd Messier object	M57 **2p**	Number which indicates the type	2 **1p**	IAU abbreviation of the constellation	Lyr **2p**
3rd Messier object	M92 **2p**	Number which indicates the type	4 **1p**	IAU abbreviation of the constellation	Her **2p**

Question 3 (15 points)

1st Star	β UMi / Kochab **2p**	Number which indicates the type	1 **1p**	IAU abbreviation of the constellation	UMi **2p**
2nd Star	γ Leo / Algieba **2p**	Number which indicates the type	2 **1p**	IAU abbreviation of the constellation	Leo **2p**
3rd Star	α CVn / Cor Caroli **2p**	Number which indicates the type	2 **1p**	IAU abbreviation of the constellation	CVn **2p**

OBSERVATIONAL PLANETARIUM

PART II Star chart
Indication

Star chart:

You have 30 minutes to finish this part.

Please use only a pencil to make the drawings and markings.

After you finish the work fill your student ID on the answer sheet as well as on the sky map.

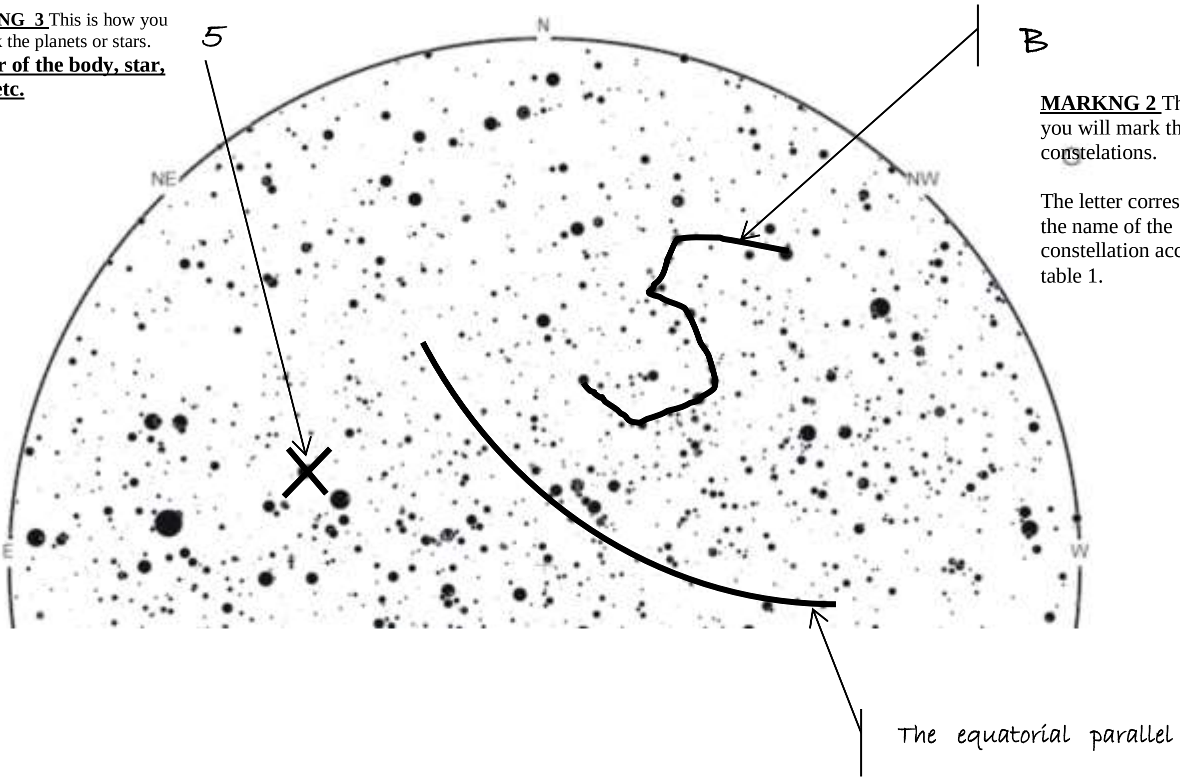
Put the answersheets in the folder; leave the compass, the ruler and the pencil on the table.

Thank you!

In this part you will use the sky-map found in the envelope. The map represents the sky in Suceava (Latitude 47^0 $39^,$ North, Longitude 26^0 15' East) on the day of the test at 22:00 local time. The observer who made the sky-map was at a very high altitude above Suceava; the Zenith point is in the center of the chart. Please use a pencil for marking and drawing lines on the sky-map. Use the example 1, 2 and 3 to draw lines and mark objects on the map, as seen in the figure bellow.

HOW TO DRAW AND MARK ON THE SKY-MAP

MARKING 3 This is how you will mark the planets or stars. **Number of the body, star, planet etc.**



MARKNG 2 This is how you will mark the constelations.

The letter corresponds to the name of the constellation according to table 1.

MARKING 1 This is how you will draw the curves/lines and indicate what it represents.

OBSERVATIONAL PLANETARIUM	PART II – outside the dome **Answer sheet**	STUDENT ID	

Please write ONLY on this side of the paper

Questions

The map represents the sky in Suceava (Latitude 47^0 39' North, Longitude 26^0 15' East) at 19:00 UT on the day of test. The observer who made the sky-map was at a very high altitude above Suceava; the Zenith point is in the center of the chart. Solve question 1 to 4 on one copy of the map and questions 5 to 8 on the second copy of map.

1. (2p) Draw on the map the horizon for an observer located on the ground in Suceava.
2. (8p) Draw the celestial equator, the ecliptic, the galactic equator and the local meridian on the map with continuous lines.
3. (9p) Mark the cardinal points (as N for north, E for east, S for south and W for west). Mark all the visible planets (except Uranus and Neptune) of the Solar System on the map and number them as 1, 2, …,6 in the order of increasing orbital radius (Skip number 3 for the Earth). Note that planets are not currently shown on the map.
4. (4p) Identify and mark the four brightest stars in visual band above the horizon line. Number the star starting from **1** – the brightest, and continue with the fainter ones till number **4** for the faintest. Fill in the following table the Bayer name of the four identified stars.

Marking on the map	1	Name of the star	
	2	Name of the star	
	3	Name of the star	
	4	Name of the star	

5. (6p) Draw on the map, approximate figures of any 15 constellations which lie completely above the horizon. Each constellation you mark should be identified on the map with the IAU abbreviation, using **Table 1**.
6. (5p) Mark on the map the positions of the following objects:
   a. The Messier objects: M31, M27, M13;
   b. β Cygni, δ Ursa Minoris.
7. (10p)

Estimate the sidereal time of the map; write the value in the box.

8. (6p)

Estimate the equatorial coordinates (right ascension and declination) of the star Altair (α Aquilae). Write your answer in the box.

α= δ=

MARKING SCHEME for Observational part2 – Chart (50 points)

Question 1 – **2p**

Question 2 – **8p** (2p for each line (2p x 4 = 8p))

Question 3 – **9p** (0.5p for each cardinal point (0.5p x 4 = 2p); 1.4p for each planet (1.4p x 5 = 7p))

Question 4 – **4p** (each star name 0.5p + at correct position in the list 0.5p)

Marking on the map	1	Name of the star	α Boo (Arcturus)
	2	Name of the star	α Lyr (Vega)
	3	Name of the star	α Aur (Capella)
	4	Name of the star	α Aql (Altair)

Question 5 – **6p** (0.4 p for each constellation (15 constellations))

Question 6 – **5p** (each object 1p)

Question 7 – **10p** (18h; +/-15m full points; +/- 30m half points)

Question 8 – **6p** (Ascension – 20h+/-1h - 3p; Declination – +10°+/-5° – 3p)

International Olympiad on Astronomy and Astrophysics

Observational Problems

(Telescope Round)

OBSERVATIONAL
TEST
OUTDOOR

Indications
READ CAREFULY

Outside the dome:

1) The observational round in the field should take a maximum of 30 minutes;
2) Please pay attention to the instructions by assistants.
3) You will be directed to a designated telescope. Here you will find attached to the clipboard the answersheet.
4) For the observational test outdoor, we are using a Newtonian telescope on equatorial mount EQ5 (D=200 mm, F=1000 mm).

   Note: the telescope is already aligned, but not necessarily calibrated – do not change the position of the tripod!

5) Fill your student ID in the box.
6) **Please write the time at the start of the observation test on the top of next page!**
7) PLEASE WRITE ONLY ON THE PRINTED SIDE OF THE ANSWER SHEET. DON'T USE THE REVERSE SIDE. The evaluator will not take into account what is written on the reverse of the answersheet.

GOOD LUCK!

OBSERVATIONAL TEST OUTDOOR	Time of start	STUDENT ID	

Questions	Answers	Space designated for the evaluator
1. Name any five constellations which will be at the meridian 2 hours from the start of your observation test.		
2. Point the telescope to M39. When you finish, ask your assistant to verify. Write in the box the number which corresponds to the object type (1 - globular cluster,2 - double cluster, 3 - open cluster, 4 - galaxy, 5 - nebula).	Number which corresponds to the object type	
3. The right ascension and the declination for β Aql (Alshain) are α=19h55m and δ=6°26'. By using the telescope find out the right ascension and the declination for δ Cep.Write down the values in the appropriate boxes.	Right ascension (α) Declination (δ)	
4. Point the telescope to the coordinate α=2h22m and δ=57°10'. When you finish, ask your assistant to verify.Write in the box the number which corresponds to the object type (1 - globular cluster, 2 - double cluster, 3 - open cluster, 4 - galaxy, 5 - nebula).	Number which corresponds to the object type	
5. Estimate UT when the meridian, the ecliptic and the equator are intersecting at the same point in this night. You may use the telescope or any other method.	Value of time	
6. Estimate the galactic latitude of ξ Dra (Grumium).		
7. Estimate the ecliptic latitude of ε Cyg (Gienah).		