VIII Международная астрономическая олимпиада
VIII International Astronomy Olympiad
VIII:e Internationella Astronomiolympiaden

Швеция, Стокгольм | 2 – 8. 10. 2003 | Stockholm, Sweden

Theoretical round. Problems to solve

язык / language	English

Group B

1. Today is the 46th anniversary of the start of the "cosmic era". History changed on October 4, 1957, when the world's first artificial satellite, ***Sputnik I***, was successfully launched. It was about the size of a basketball, a sphere of 580 mm in diameter with a mass of 83.6 kg and a 2 mm thick surface of highly polished aluminium alloy. The Russian word "sputnik" means "companion" ("satellite" in the astronomical sense). Sputnik I had an elliptical orbit – at perigee, just after launch, it was 227 km from the Earth's surface, and 945 km at apogee. It remained in orbit until January 4, 1958.
   Estimate (with necessary figures and calculations), whether was it possible to observe the satellite with the naked eye.
2. Estimate with order-of-magnitude accuracy how many degrees it would be possible to raise temperature of water in a normal swimming pool ($50 \times 20 \times 2$ m) if one was able to collect all energy which "stellar" astronomers used untill to obtaining knowledge about the structure of the Universe, observing at night on optical telescopes. The heat capacity of water is 4200 J/(kg·K). The Total Solar Irradiation Constant is equal to 1.37 kW/m^2. List in a table all the parameters and assumptions you have used in your solution.
3. The White Bear from the previous International Astronomy Olympiad is still sitting at the North Pole. But this year a follower has appeared – a Penguin sitting at South Pole. Recently, after the ending of polar night, the Penguin observed the sunrise. What did the Bear observe at this time? Draw what the White Bear saw at the moment when the Penguin observed exactly half of the solar disk on the horizon. Assume that the Earth is spherical. The answer should be explained by drawing a figure with an image of the Bear on North Pole; necessary sizes or angular sizes should be in the picture. Recollect for yourself the necessary information about the animals.
4. The Great Opposition of Mars took place this year on August 28 at $17^h 56^m$ UT. The next Great Opposition of Mars will take place in summer 2018. Somebody did not understand and, instead, imagined that 2018 will be the year not for the next Great Opposition but simply next opposition. Find parameters of the orbit of such a hypothetical planet, «Mars-2», and estimate its magnitude visible from Earth during the mean opposition. Consider the orbit of «Mars-2» to be circular and its physical characteristics the same as for Mars.
5. Every day an astronomer makes observations at the same moment of the Local Sidereal Time, and always notices the Sun just on the mathematical horizon. Where and when the observations are carried out? Your answer must contain both explanations and explicit figures (possible coordinates, etc.)
6. Even the ancient Greeks knew that the size of the Earth is small compared to the distances to the stars. For example, in one myth it is told that the god Hephaestus once carelessly dropped his anvil on the Earth. It took nine whole days before the anvil hit the earth. Estimate "the height of the sky" according to the representations of the ancient Greeks and compare it to the distances of objects known to you.

Data from the “Table of planetary data” may be used for solving of every problem.

Задачи практического тура **Practical round. Problems to solve**

язык / language	English

Groups A,B

7. Measuring the speed of light

Note: You must carefully account for every step in your calculations. Answers without motivation will not be accepted.

Imagine that the solar system in a distant future becomes inhabited by our descendants. On the asteroid *Saltis*, a small robotic mining establishment is supervised by Celesta Spacedigger, who also happens to be a dedicated amateur astronomer. Being bored by her job, Celesta spends the long nights of Saltis studying the stars and the planets, in particular the glorious planet Saturn. An old but reliable astronomical almanac helps her keeping track of celestial events like eclipses of the moon Titan by its planet Saturn. To her dismay, however, Celesta starts to note large deviations between her observed times of the eclipses of Titan and the tabulated ones. After years of careful observations (she has a long term assignment on Saltis) she begins to see a pattern; the deviations are largest when Saturn is close to opposition or conjunction (with the Sun, as seen from Saltis). She realises that this must be due to the finite speed of light, and a check in her almanac confirms that the tabulated timings are *heliocentric*, that is, as seen from the Sun, and not as seen from Saltis. Quite satisfied with her discovery, Celesta use her observations to calculate the speed of light.

In this problem you are asked to repeat Celesta's calculations by using her observations. The units of length and time that Celesta uses are a bit different from what you are used to. The unit of time is called *pinit*, and is defined such that there are 1000 pinit in one synodic rotation of Saltis. The length unit is called *seter* and is defined to be one billionth (10^{-9}) of the mean distance between the Sun and Saltis.

Table 1 *Eclipses of Titan by Saturn*

Tabulated[a] (pinit)	Celesta[b] (pinit)	Comment[c]
456.47	450.32	Opposition
18.50	12.28	Opposition
821.41	815.29	Opposition
444.70	450.85	Conjunction
615.43	621.52	Conjunction
791.94	798.02	Conjunction

[a] The tabulated values refer to when an observer located at the Sun would observe the beginning of the eclipse.

[b] Celesta observed timing of the beginning of the eclipses from Saltis. Her estimated accuracy in the timing is 0.03 pinit.

[c] The position of Saturn during an eclipse of Titan was never exactly in opposition or conjunction, but close to.

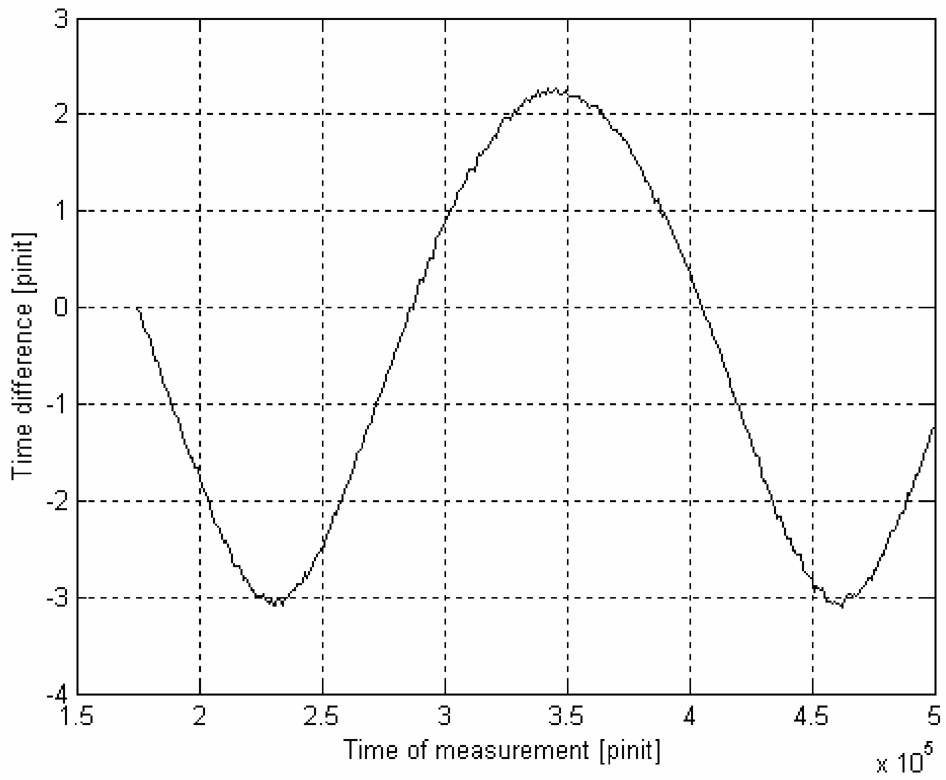

Figure 1 *Difference between Celesta's watch and the time signal received from Earth.*

7.1. Celesta observed eclipses of Titan when Saturn was close to opposition or conjunction during six occasions (Table 1). Analyse her data carefully and estimate the speed of light, in units of seter per pinit, and give the expected error of your estimate. (50%)

Celesta also enjoys listening to radio signals from Earth during her lonely days. With her re-discovery of the finite speed of light, Celesta gained enough confidence to try and measure the orbital radius of Earth (in seter). She synchronises her very accurate watch with a radio time signal from Earth, and then regularly follows how the time of her watch differs from the periodic time signal. Her measurements are presented in Fig. 1.

7.2. Use Celesta's data in Fig. 1 to estimate the radius of Earth's orbit in seter. (20%)

7.3. With 1 AU = $149.6 \cdot 10^6$ km and $c = 2.998 \cdot 10^8$ m/s, how many meter is a seter? How many seconds is a pinit? (10%)

7.4. Estimate the orbital period (in years) of Saltis from Fig. 1 and the answer to problem 3. (20%)

Attention: for group A there is the only problem Nr.7 on the Practical round for 3 hours; for group B there are the two problems: Nr.7 and Nr.8 for 4 hours.

Задачи практического тура   **Practical round. Problems to solve**

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Group B

8. Estimating the mass of Saturn

Introduction

Ever since Galileo Galilei observed the ring of Saturn through a telescope for the first time, it has been regarded as one of the prime astronomical sights. The ring itself is not a rigid body, but consists of innumerable moonlets in Keplerian orbits around the planet, as shown spectroscopically almost simultaneously by Aristarkh A. Belopolsky and by James E. Keeler. The results of the latter were published in the very first issue of the Astrophysical Journal in 1895. In this problem, you are asked to repeat their argument using recent observations, and estimate the mass of Saturn.

Observational details

Saturn was observed by the Nordic Optical Telescope (NOT, a 2.5 m telescope on the Canary Island La Palma) 2002-02-25 at 23:25 Universal Time. A spectroscopic slit was placed over the planet as shown by Fig. 1. The retrieved spectrum (Fig. 2) shows the solar spectrum reflected on the planet. The straight vertical absorption lines are telluric, i.e. absorption lines arising when the light travels through the Earth's atmosphere, while the lines seen at inclination are the solar absorption lines reflected against the planet. The two strongest absorption lines seen in the spectrum are from the Na I (neutral sodium) D_2 and D_1 transitions, at rest wavelengths 589.00 nm and 589.59 nm respectively.

Problems

Note: You must carefully account for every step in your calculation. Answers without motivation will not be accepted.

8.1. The spectrum of Fig. 2 implies that the ring of Saturn cannot be a rigidly rotating body. Draw a figure that qualitatively shows what the spectrum would look like, if the ring was indeed rotating rigidly. (~20%)

8.2. The sidereal rotation period of Saturn is known to be 10.66 hours. Estimate the equatorial diameter of Saturn from the spectrum of Fig. 2. (~30%)

8.3. Estimate the mass of Saturn implied by the spectrum of Fig. 2. If you cannot remember the gravitational constant, you may use that 1 AU = 1.496×10^8 km and the mass of the Sun is $M_{Sun} = 1.99\times10^{30}$ kg. (~50%)

You may use the fact that the ring of Saturn is planar and parallel to the planet's equator to calculate the inclination of the system relative to the line of sight.

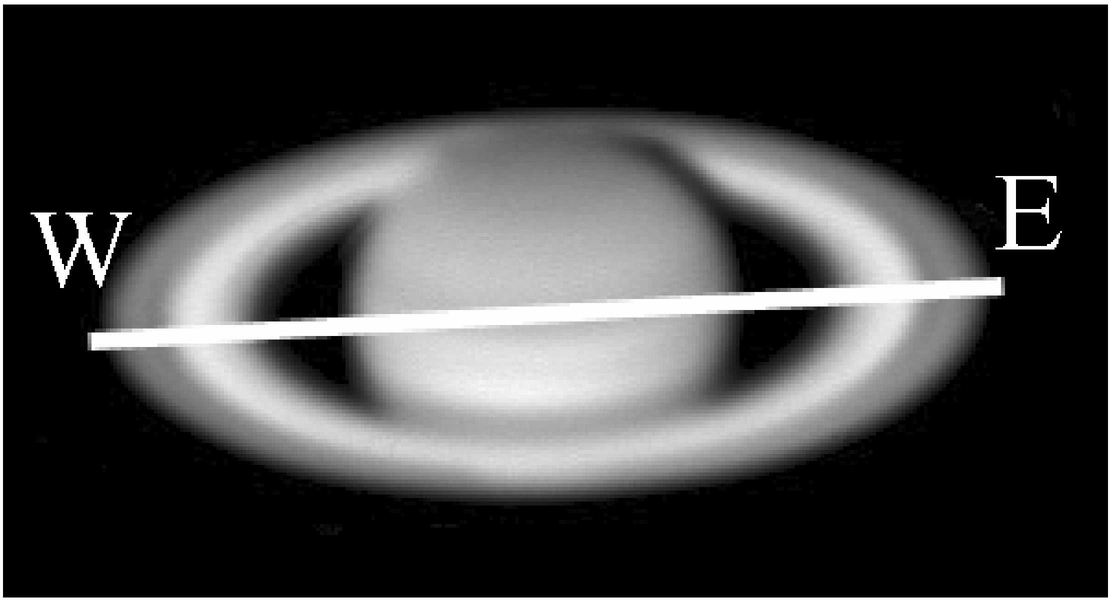

Figure 1
Position of the spectroscopic slit on Saturn. West and East are marked by W and E respectively.

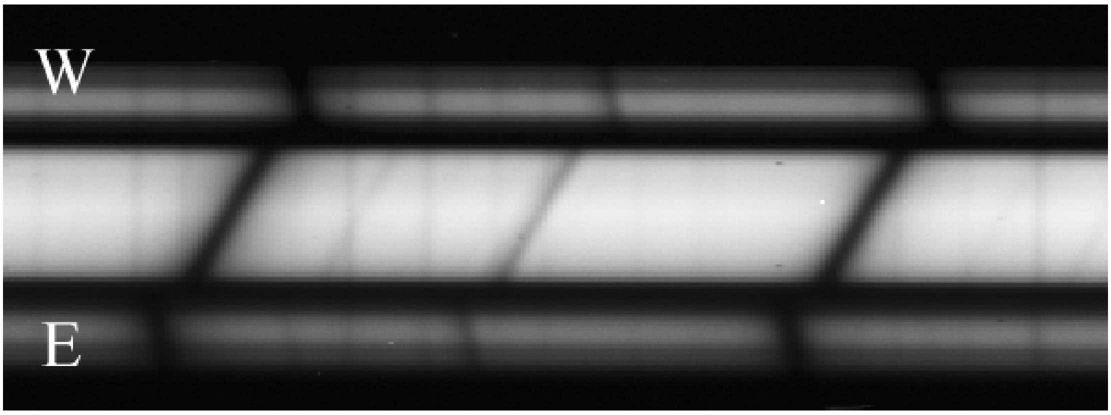

Figure 2
The solar spectrum reflected on Saturn. West is up, and wavelengths increasing to the right.