Theoretical round. Problems to solve

General note. Maybe not all problems have correct questions. Some questions (maybe the main question of the problem, maybe one of the subquestions) may make no real sense. In this case you have to write in your answer (in English or Russian): «**impossible situation – ситуация невозможна**». Of course, this answer has to be explained numerically or logically.

Data from the tables (Planetary data, stars, constants, etc.) may be used for solving every problem.

The answers «Да-Yes» or «Нет-No» has to be written in English or Russian.

1. **Observation of a star.** Observations were done by the naked eye on June 16, 2008, Universal time was used. An observer has registered that a star passed zenith at 0^h18^m, and at 8^h17^m its height above the horizon was 87°12'. Find the latitude of the observations.

2. **Planetarium.** Classical devices "planetaria" are arranged so that each group of stars is projected on a dome by a small optical system. Foils with hole-stars of the corresponding sizes are often used as these "slides" of constellations which are projected on the dome, so that most of the light is blocked by the foil (the black sky appears), and only light through the holes are transmitted (so stars appear). For example, images of 0^m stars on the foil have the size $l_0 = 0.1$ mm, and stars up to 6^m are demonstrated, the focal length of the projecting system is f = 25 cm, and the device has 16 separate projecting systems for every hemisphere. The dome of the planetarium of the observatory "Bobek" has a diameter of 2R = 10 m.

   Let's suppose that all slides have been removed for replacement by more perfect ones, and the whole light began to be projected on the dome. What would the total stellar magnitude of the illuminated dome be (the artificial gray sky)? Would it be possible to read a newspaper in such an illuminance?

   The answer has to include a list of the necessary parameters with formulae and numerical values.

3. **Sunrise on Mars.** The Polar Bear (whom was already met in the texts of many International Astronomy Olympiads) was tired to make astronomical observations on Earth. He made a fascinating journey to the North Pole of Mars, and decided to observe a sunrise there. Calculate how long this sunrise lasts. The solution has to include a picture with an image of the Bear on the North Pole of Mars. Necessary sizes or angular sizes should be in the picture. Assume that Mars is spherical and its orbit may be considered circular. Recollect for yourself the necessary information about the Polar Bear.

4. **Photo of Jupiter.** In the photo of Jupiter that was taken on October 19, 2009, one of the Galilean moons and its shadow on the disc of the planet can be seen. Jupiter was near the middle of Capricornus constellation when the photo was taken.

   Find the orbital distance from the moon to the surface of the planet. Determine the name of the moon. The solution should be illustrated by drawings. The name of the moon in the solution and in the drawings should be written (or duplicated) in English.

5. **Jupiter disappeared.** Let us suppose that Jupiter suddenly disappeared. The moons of Jupiter became independent bodies.

   5.1. Which former Galileo moon(s) and in what case may leave the Solar system?

   5.2. Which former Galileo moon(s) and in what case may fall into the Sun?

   The answers "which moon" and "in what case" (configurations at the moment of Jupiter disappearance) have to be given in the form of drawings, and calculations should be the base for the answers. The names of the moons in the solution and in the drawings should be written in English. Consider the orbit of Jupiter (before its disappearance) to be circular.

Theoretical round. Problems to solve

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Data from the tables (Planetary data, stars, constants, etc.) may be used for solving every problem.

The answers «Да-Yes» or «Нет-No» has to be written in English or Russian.

1. **Solar radiation.** Find, with how many percents the mass of the Sun is diminishing per year due to its radiation.

2. **Planetarium.** Classical devices "planetaria" are arranged so that each group of stars is projected on a dome by a small optical system. Consider the planetarium of observatory “Bobek” which diameter of the hall (dome) is $2R = 10$ m. On slides of the constellations projected on the dome images of 0^m stars have the size $l_0 = 0.1$ mm (foils with hole-stars of the mentioned size are often used as these "slides").

   2.1. Estimate what the parameters should be (decide yourself, which parameters are important here) of the objective of this optical system, so that the visitors sitting in the centre of the hall of the planetarium would perceive the "stars" as points (not as circles or nebulae).

   2.2. Let's suppose that all slides have been removed for replacement by more perfect ones, and all the light began to be projected on the dome. What would the total stellar magnitude of the illuminated dome be (the artificial gray sky)? Would it be possible to read a newspaper in such an illuminance?

   The answers has to include a list of the necessary parameters with formulae and numerical values.

3. **Sunrise on Mars.** The Polar Bear (whom was already met in the texts of many International Astronomy Olympiads) was tired to make astronomical observations on Earth. He made a fascinating journey to the North Pole of Mars, and decided to observe a sunrise there. Calculate how long this sunrise lasts. The solution has to include a picture with an image of the Bear on the North Pole of Mars. Necessary sizes or angular sizes should be in the picture. Assume that Mars is spherical and its orbit may be considered circular. Recollect for yourself the necessary information about the Polar Bear.

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Задачи теоретического тура. Рисунок

Theoretical round. Problems to solve. Picture

4. Снимок Юпитера.

4. Photo of Jupiter.

Элементы орбит. Физические характеристики Солнца, некоторых планет, Луны и Галилеевых спутников Юпитера

Parameters of orbits. Physical characteristics of Sun, some planets, Moon and Galilean moons of Jupiter

Небесное тело, планета	Среднее расстояние от центрального тела		Сидерический (или аналогичный) период обращения		Эксцентриситет, *e*	Экваториальн. диаметр *км*	Масса 10^{24} *кг*	Средняя плотность $г/см^3$	Ускор. своб. пад. у пов. $м/с^2$	Наклон оси	Альбедо
	в *астр. ед.*	в *млн. км*	в тропич. годах	в средних сутках							
Body, planet	Average distance to central body		Sidereal (or analogous) period		Eccentricity *e*	Equat. diameter *km*	Mass 10^{24} *kg*	Av. density g/cm^3	Grav. acceler. at surf. m/s^2	Axial tilt	Albedo
	in *astr. units*	in *mln. km*	in troph. years	in days							
Солнце Sun	$1{,}6\cdot10^{9}$	$2{,}5\cdot10^{11}$	$2{,}2\cdot10^{8}$	$8\cdot10^{10}$		1392000	1989000	1,409			
Меркурий Mercury	0,387	57,9	0,241	87,97	0,206	4 879	0,3302	5,43	3,70	0,01°	0,06
Венера Venus	0,723	108,2	0,615	224,70	0,007	12 104	4,8690	5,24	8,87	177,36	0,78
Земля Earth	1,000	149,6	1,000	365,26	0,017	12 756	5,9742	5,515	9,81	23,44	0,36
Луна Moon	0,00257	0,38440	0,0748	27,3217	0,055	3 475	0,0735	3,34	1,62	6,7	0,07
Марс Mars	1,524	227,9	1,880	686,98	0,093	6 794	0,6419	3,94	3,71	25,19	0,15
Юпитер Jupiter	5,204	778,6	11,862	4 332,59	0,048	142 984	1899,8	1,33	24,86	3,13	0,66
Сатурн Saturn	9,584	1433,7	29,458	10 759,20	0,054	120 536	568,50	0,70	10,41	26,73	0,68

Спутник	Среднее расстояние от центра планеты		Сидерич. период обращения в средних сутках	Наклонение орбиты (°)	Эксцентриситет, *e*	Диаметр *км*	Масса 10^{21} *кг*	Средняя плотность $г/см^3$	Ускор. своб. пад. у пов. $м/с^2$	Макс. блеск, вид. с Земли *)	Геом Альбедо
	в *астр. ед.*	в *тыс. км*									
Moon	Average distance to planet center		Sidereal period	Orbit inclination	Eccentricity *e*	Diameter *km*	Mass 10^{21} *kg*	Av. density g/cm^3	Grav. acceler. at surf. m/s^2	Max. magn. From Earth *)	Geom Albedo
	in *astr. units*	in *thous. km*	in days	(°)							
Ио Io	0,00282	421,70	1,769137	0,050°	0,0041	3 643	89,31	3,53	1,80	$5{,}02^{m}$	0,63
Европа Europa	0,00449	671,03	3,551181	0,471°	0,0094	3 122	48,00	3,01	1,32	$5{,}29^{m}$	0,67
Ганимед Ganymede	0,00716	1070,41	7,154553	0,204°	0,0011	5 262	148,19	1,94	1,43	$4{,}61^{m}$	0,43
Каллисто Callisto	0,01259	1882,71	16,689018	0,205°	0,0074	4 821	107,59	1,83	1,23	$5{,}65^{m}$	0,20

*) В среднем противостоянии. *) In mean opposition.

Некоторые константы и формулы

Some constants and formulae

Скорость света в вакууме, c (м/с)	299 792 458	Speed of light in vacuum, c (m/s)
Гравитационная постоянная, G (Н·м^2/кг^2)	$6.674 \cdot 10^{-11}$	Constant of gravitation, G (N·m^2/kg^2)
Солнечная постоянная, A (Вт/м^2)	1367	Solar constant, A (W/m^2)
Параметр Хаббла, H_0 (км/с/МПк) — среднее значение диапазон значений	71 50-100	mean value diapason of values — Hubble parameter, H_0 (km/s/Mpc)
Постоянная Планка, h (Дж·с)	$6.626 \cdot 10^{-34}$	Plank constant, h (J·s)
Заряд электрона, e (Кл)	$1.602 \cdot 10^{-19}$	Charge of electron, e (C)
Масса электрона, m_e (кг)	$9.109 \cdot 10^{-31}$	Mass of electron, m_e (kg)
Соотношение масс протона и электрона	1836.15	Proton-to-electron ratio
Постоянная Фарадея, F (Кл/моль)	96 485	Faraday constant, F (C/mol)
Магнитная постоянная, μ_0 (Гн/м)	$1.257 \cdot 10^{-6}$	Magnetic constant, μ_0 (H/m)
Универсальная газовая постоянная, R (Дж/моль/K)	8.314	Universal gas constant, R (J/mol/K)
Постоянная Больцмана, k (Дж/K)	$1.381 \cdot 10^{-23}$	Boltzmann constant, k (J/K)
Стандартная атмосфера (Па)	101 325	Standard atmosphere (Pa)
Постоянная Стефана-Больцмана, σ (Вт/м^2/K^4)	$5.670 \cdot 10^{-8}$	Stefan-Boltzmann constant, σ (W/m^2/K^4)
Константа смещения Вина, b (м·K)	0.002897	Wien's displacement constant, b (m·K)
Лабораторная длина волны Hα (Å)	6562.81	Laboratory wavelength of Hα (Å)
Длина тропического года, T (сут)	365.242199	Tropical year length, T (days)
Показатель преломления воды при 20°C, n	1.334	Refractive index of water for 20°C, n
Момент инерции шара	$I = {}^2/_5\, MR^2$	Moment of inertia of a solid ball
Площадь сферы	$S = 4\pi R^2$	Area of sphere
π	3.14159265	π
e	2.71828183	e
Золотое сечение, φ	1.61803399	Golden ratio, φ