XV Международная астрономическая олимпиада
XV International Astronomy Olympiad

Крым, Судак 16 – 24. X. 2010 Sudak, Crimea

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 have 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 table of planetary data may be used for solving every problem.

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

1. **Circumpolar stars.** Usually we consider that there are about 6000 stars in the whole sky which are visible to the naked eye. The refraction near the horizon is 35'. Find, how many more stars visible to the naked eye become circumpolar (which means that they never set) due to refraction:

   1.1 for observer on the North Pole at zero height position (like Polar Bear in a position with its eyes at zero height).

   1.2 for observer on the Equator at zero height position (like Giraffe with the eyes lowered to zero level).

   In your solution include a picture with an image of the Bear on the ices of North Pole and the Giraffe on the Equator, and necessary dimensions and/or angular dimensions used.

2. **Observation of a star.** A star is observed from the Earth. It is found that its magnitude is $m_1 = 2^m.74$ when observed at Zenith and $m_2 = 2^m.85$ when observed at 45° above the horizon. What would the apparent magnitude m_0 of the star be if observed from above the atmosphere (from a satellite, for example)?

3. **Parallax.** Like humans, astronomers of Mercury use the same method for definitions of parallaxes and of parsec but measure them in different (their own) units. For example, the distance to Sirius equals to 1.406 mepc (1.406 mercurial parsec).
   - Describe the most evident system of angular units used by astronomers of Mercury.
   - Calculate the mercurial diurnal parallax of the Sun and write the answer in "meau" (mercurial angular units – the common angular units for astronomers of Mercury).

4. **Climate.** There is a reference to climate in Crimea according to observations during 934 months between 1821 and 1991 on the web-site of the XV IAO. The average temperatures in Simferopol in January and July are equal to –0.4° C and +21.2° C respectively according to that data. Imagine a planet whose axis of rotation is perpendicular to the planets' ecliptic. Estimate, what the eccentricity of the planets' orbit should be in order to give climatic seasons identical to the ones in Crimea.

5. **Cosmonaut.** Imagine a small space station with a total mass of M = 50 ton placed far away from any celestial body. A cosmonaut with a total mass (with ammunitions) of m = 100 kg appears L = 80 m away from the station without any fuel. Calculate (estimate) the time τ after which the cosmonaut reaches the station due to gravitational attraction. Consider the initial velocity of the cosmonaut to be zero.

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3. **Parallax.** Like humans, astronomers of Venus use the same method for definitions of parallaxes and of parsec but measure them in different (their own) units. For example, the distance to Sirius equals to 19.6 vpc (19.6 venusial parsec).
   - Describe the most evident system of angular units used by astronomers of Venus.
   - Calculate the venusial diurnal parallax of the Sun and write the answer in "vau" (venusial angular units – the common angular units for astronomers of Venus).

   Note: citizens of Venus have two hands (as humans), and 7 fingers at each hand.

4. **White dwarf.** The absolute stellar magnitude of a white dwarf is 14^m. Humanoids create a planet similar to the Earth by all parameters (including atmosphere and climate) rotating around this white dwarf. Calculate (estimate) the minimal possible sidereal period of the planet.

5. **International Space Station.** The graph presents the change in height of the ISS orbit depending on time. Estimate the average density of the atmosphere at heights around 340-360 km. Consider the orbit to be circular. The mass of ISS is 362 ton. Consider the cross-section of the ISS-complex to be $S = 500\ m^2$ (including the sections of the solar cell array).

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)	$6.674\cdot10^{-11}$	Constant of gravitation, G (N·m^2/kg^2)
Солнечная постоянная, A (Вт/м^2)	1367	Solar constant, A (W/m^2)
Постоянная Хаббла, H_0 (км/с/МПк) — среднее значение / диапазон значений	70 50-100	mean value / diapason of values — Hubble constant, H_0 (km/s/Mpc)
Постоянная Планка, h (Дж·с)	$6.626\cdot10^{-34}$	Plank constant, h (J·s)
Заряд электрона, e (Кл)	$1.602\cdot10^{-19}$	Charge of electron, e (C)
Масса электрона, m_e (кг)	$9.109\cdot10^{-31}$	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)	$1.257\cdot10^{-6}$	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)	$1.381\cdot10^{-23}$	Boltzmann constant, k (J/K)
Стандартная атмосфера (Па)	101 325	Standard atmosphere (Pa)
Постоянная Стефана-Больцмана, σ (Вт/м^2/K^4)	$5.670\cdot10^{-8}$	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)	6563	Laboratory wavelength of Hα (Å)
Показатель преломления воды при 20°C, n	1.334	Refractive index of water for 20°C, n
Площадь сферы	$S = 4\pi R^2$	Area of sphere
π	3.14159265	π

Данные о некоторых звёздах

Data of some stars

			RA	DEC	*p*	m	SC
Арктур	Arcturus	α Boo	$14^h\ 15^m\ 40^s$	19° 10' 57"	0".089	-0.05	K1
Вега	Vega	α Lyr	$18^h\ 36^m\ 56^s$	38° 47' 01"	0".129	0.03	A0
Денеб	Deneb	α Cyg	$20^h\ 41^m\ 26^s$	45° 16' 49"	0".001	1.25	A2
Полярная	Polaris	α UMi	$02^h\ 31^m\ 51^s$	89° 15' 51"	0".007	2.02	F7
Сириус	Sirius	α CMa	$06^h\ 45^m\ 09^s$	-16° 42' 58"	0".379	-1.46	A1

Элементы орбит.
Физические характеристики некоторых планет, Луны, Солнца и Эриды

Parameters of orbits.
Physical characteristics of some planets, Moon, Sun and Eris

Небесное тело, планета	Среднее расстояние от центрального тела		Сидерический (или аналогичный) период обращения		Эксцентриситет,	Экваториальн. диаметр	Масса	Средняя плотность	Ускор. своб. пад. у пов.	Макс. блеск, вид. с Земли **)	Альбедо
	в *астр. ед.*	в *млн. км*	в тропич. годах	в средних сутках	*e*	*км*	10^{24} *кг*	*г/см*^{3}	*м/с*^{2}		
Body, planet	Average distance to central body		Sidereal (or analogous) period		Eccentricity	Equat. diameter	Mass	Av. density	Grav. acceler. at surf.	Max. magn. from Earth **)	Albedo
	in *astr. units*	in *mln. km*	in troph. years	in days	*e*	*km*	10^{24} *kg*	*g/cm*^{3}	*m/s*^{2}		
Солнце Sun	$1,6\cdot10^9$	$2,5\cdot10^{11}$	$2,2\cdot10^8$	$8\cdot10^{10}$		1392000	1989000	1,409		$-26,8^m$	
Меркурий Mercury	0,387	57,9	0,241	87,97	0,206	4 879	0,3302	5,43	3,70		0,06
Венера Venus	0,723	108,2	0,615	224,70	0,007	12 104	4,8690	5,24	8,87		0,78
Земля Earth	1,000	149,6	1,000	365,26	0,017	12 756	5,9742	5,515	9,81		0,36
Луна Moon	0,00257	0,38440	0,0748	27,3217	0,055	3 475	0,0735	3,34	1,62	$-12,7^m$	0,07
Марс Mars	1,524	227,9	1,880	686,98	0,093	6 794	0,6419	3,94	3,71	$-2,0^m$	0,15
Юпитер Jupiter	5,204	778,6	11,862	4 332,59	0,048	142 984	1899,8	1,33	24,86	$-2,7^m$	0,66
Сатурн Saturn	9,584	1433,7	29,458	10 759,20	0,054	120 536	568,50	0,70	10,41	$0,7^m$	0,68
Эрида Eris	68,01			204 862	0,434	2 600	0,0167		0,8		0,86

**) Для Луны – в среднем противостоянии.
**) For Moon – in mean opposition.

График к задаче 5

Graph for problem 5