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**» have to be written in English or Russian.

1. **Transit of Venus.** Recently, on June 6, 2012, an infrequent astronomical phenomenon, transit of Venus across the solar disc, took place. The next transit of Venus will take place only in 2117. Calculate the date of that transit. (Answer without calculations will not be considered even as a partial solution.)

2. **Transit of Pseudovenus.** Recently, on June 6, 2012, an infrequent astronomical phenomenon, transit of Venus across the solar disc took place. Suppose somebody did not understand the phenomenon and ascribed it not to transit of real Venus but of some moon, which we name Pseudovenus, rotating around the Earth in a circular orbit. Find the radius of the orbit of Pseudovenus and diameter of this sky body. Effects due to axial rotating of the Earth should not be taken into account.

3. **Old persons' star.** There is ancient legend in Korea that says, if you managed to see the "Old persons' star" thrice, you are lucky person and will live a long life. The "Old persons' star", now known as Canopus, was seen brighter and better in past times, but even now sometimes one can see this star in Korea. Estimate approximately what visible stellar magnitude Canopus may have when observing it from the southern coast of Jeju island (Korea) in the most favorable conditions. The territory of the island is located at latitudes between 33°12' N and 33°34' N and longitudes between 126°09' E and 126°57' E. Take from the tables and recollect for yourself the necessary additional information.

4. **Altair.** Estimate the density of the star Altair.

5. **Venus and Earth.** At what maximum distance from the Venus ecliptic the Earth can be visible at the sky from Venus (actually, from a point outside the Venus atmosphere)? Orbits of the planets may be considered circular.
   Estimate the stellar magnitude of the Earth in this situation.

6. **Remote galaxy.** Astronomers have discovered a distant galaxy that in the Earth's sky, at the first glance looks like ε Eridani, the same in colour, but 1000 times less in intensity. It appears, however, that this galaxy is composed only of stars similar to the Sun in physical characteristics. Find the number of stars in the galaxy.

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 / Body, planet	Среднее расстояние от центрального тела / Average distance to central body		Сидерический (или аналогичный) период обращения / Sidereal period (or analogous)		Наклон орбиты, / Orbital inclination,	Эксцентриситет, / Eccentricity	Экваториальн. диаметр / Equat. diameter	Масса / Mass	Средняя плотность / Av. density	Ускор. своб. пад. у пов. / Grav. accelr. at surf.	Наклон оси / Axial tilt	Макс. блеск, вид. с Земли **) / Max. magn. From Earth **)	Альбедо / Albedo
	в *астр. ед.* / in *astr. units*	в *млн. км* / in 10^6 *km*	в тропич. годах / in tropical years	в средних сутках / in days	*i*	*e*	*км* / *km*	10^{24} *кг* / 10^{24} *kg*	*г/см*^{3} / *g/cm*^{3}	*м/с*^{2} / *m/s*^{2}			
Солнце Sun	$1{,}6\cdot10^9$	$2{,}5\cdot10^{11}$	$2{,}2\cdot10^8$	$8\cdot10^{10}$			1392000	1989000	1,409			$-26{,}74^m$	
Меркурий Mercury	0,387	57,9	0,241	87,969	7,00°	0,206	4 879	0,3302	5,43	3,70	0,01°		0,06
Венера Venus	0,723	108,2	0,615	224,7007	3,40	0,007	12 104	4,8690	5,24	8,87	177,36		0,78
Земля Earth	1,000	149,6	1,000	365,2564	0,00	0,017	12 756	5,9742	5,515	9,81	23,44		0,36
Луна Moon	0,00257	0,38440	0,0748	27,3217	5,15	0,055	3 475	0,0735	3,34	1,62	6,7	$-12{,}7^m$	0,07
Марс Mars	1,524	227,9	1,880	686,98	1,85	0,093	6 794	0,6419	3,94	3,71	25,19	$-2{,}0^m$	0,15
Юпитер Jupiter	5,204	778,6	11,862	4 332,59	1,30	0,048	142 984	1899,8	1,33	24,86	3,13	$-2{,}7^m$	0,66
Сатурн Saturn	9,584	1433,7	29,458	10 759,20	2,48	0,054	120 536	568,50	0,70	10,41	26,73	$0{,}7^m$	0,68
Эрида Eris	68,05			205 029	43,82	0,435	2 326	0,0167	2,52	0,7			0,96

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

XVII Международная астрономическая олимпиада
XVII International Astronomy Olympiad

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·м²/кг²)	$6.674 \cdot 10^{-11}$	Constant of gravitation, G (N·m²/kg²)
Солнечная постоянная, A (Вт/м²)	1367	Solar constant, A (W/m²)
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/К)	8.314	Universal gas constant, R (J/mol/K)
Постоянная Больцмана, k (Дж/К)	$1.381 \cdot 10^{-23}$	Boltzmann constant, k (J/K)
Постоянная Стефана-Больцмана, σ (Вт/м²/К⁴)	$5.670 \cdot 10^{-8}$	Stefan-Boltzmann constant, σ (W/m²/K⁴)
Константа смещения Вина, b (м·К)	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)
Стандартная атмосфера (Па)	101 325	Standard atmosphere (Pa)
Ослабление видимого света земной атмосферой в зените (минимально)	19%, 0.23^m	Visible light extinction by the terrestrial atmosphere in zenith (minimum)
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

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Данные о некоторых звёздах
Data of some stars

			RA	DEC	p	m	S C	масса mass
Солнце	Sun	Θ	$0^h - 24^h$	-23°26' +23°26'	8".794	$-26^m.74$	G2	1 $M_\odot$
Альдебаран	Aldebaran	α Tau	$04^h\ 35^m\ 55^s$	16° 30' 33"	0".048	$0^m.85^v$	K5	2.5 $M_\odot$
Альтаир	Altair	α Aql	$19^h\ 50^m\ 47^s$	08° 52' 06"	0".195	$0^m.77$	A7	1.7 $M_\odot$
Антарес	Antares	α Sco	$16^h\ 29^m\ 24^s$	-26° 25' 55"	0".006	$0^m.96$	M1+B4	22.4 $M_\odot$
Арктур	Arcturus	α Boo	$14^h\ 15^m\ 40^s$	19° 10' 57"	0".089	$-0^m.04^v$	K1	1.1 $M_\odot$
Ахернар	Achernar	α Eri	$01^h\ 37^m\ 43^s$	-57° 14' 12"	0".026	$0^m.46$	B3	
зв.Барнарда	Barnard's star	Oph	$17^h\ 57^m\ 48^s$	04° 41' 36"	0".545	$9^m.54$	M4	
Бетельгейзе	Betelgeuse	α Ori	$05^h\ 55^m\ 10^s$	07° 24' 25"	0".005	$0^m.5^v$	M1	
Вега	Vega	α Lyr	$18^h\ 36^m\ 56^s$	38° 47' 01"	0".129	$0^m.03$	A0	
Денеб	Deneb	α Cyg	$20^h\ 41^m\ 26^s$	45° 16' 49"	0".002	$1^m.25$	A2	
Канопус	Canopus	α Car	$06^h\ 23^m\ 57^s$	-52° 41' 45"	0".010	$-0^m.72$	F0	
Капелла	Capella	α Aur	$05^h\ 16^m\ 41^s$	45° 59' 53"	0".073	$0^m.08$	G5+G0	
Полярная	Polaris	α UMi	$02^h\ 31^m\ 49^s$	89° 15' 51"	0".0076	$1^m.97^v$	F7	
Процион	Procyon	α CMi	$07^h\ 39^m\ 18^s$	05° 13' 30"	0".288	$0^m.38$	F5	
Ригель	Rigel	β Ori	$05^h\ 14^m\ 32^s$	-08° 12' 06"	0".013	$0^m.12$	B8	
Сириус	Sirius	α CMa	$06^h\ 45^m\ 09^s$	-16° 42' 58"	0".375	$-1^m.46$	A1	
Спика	Spica	α Vir	$13^h\ 25^m\ 12^s$	-11° 09' 41"	0".023	$0^m.98$	B1	
Альфа Центавра	Alpha Centauri	α Cen	$14^h\ 39^m\ 36^s$	-60° 50' 07"	0".751	$-0^m.01$ $1^m.33$	G2 K1	2.0 $M_\odot$
Бета Центавра	Beta Centauri	β Cen	$14^h\ 03^m\ 49^s$	-60° 22' 23"	0".009	$0^m.61$	B1	21 $M_\odot$
Эпсилон Эридана	Epsilon Eridani	ε Eri	$03^h\ 32^m\ 56^s$	-09° 27' 30"	0".311	$3^m.74$	K2	0.82 $M_\odot$

Диаграмма Герцшпрунга-Рассела **Hertzsprung-Russell diagram**