Theoretical round. Problems to solve

1. **Mercury mirror.** As you know, if one rotates a vessel with mercury, its surface will take a parabolic form. A liquid mirror obtained in this way can be used as the main mirror of a telescope. The Polar Bear-astronomer living in the Arctic decided to use this idea and build such a telescope exactly at the North Pole, and use the daily revolution of the Earth as the rotation mechanism so that the main mirror would have a long focal length.

   1.1. Is the Polar Bear idea feasible? (Write "**Yes**" or "**No**" in English.) If yes, then find the focal length of the resulting liquid mirror, and if not, prove your conclusion by doing the necessary calculations and drawings.

   1.2. Include an artistic picture with an image of the Bear-astronomer, engaged in the implementation of his project.

2. **Great oppositions of Mars.** On the morning of July 27, 2018, Mars was in a great opposition (see attached ephemeris). The great oppositions of Mars (the situations when this planet is seen most brightly in comparison with the visibility during other oppositions) are repeated every 15 or 17 years. So the previous opposition (which is also called the "greatest", since Mars was so bright only once in many centuries) was on August 28, 2003, and the next one will occur in 2035.

   2.1. Determine the constellation, in which Mars was during this year opposition.

   2.2. Considering the orbits of the Earth and Mars as circular, and based on the date of opposition 2003, calculate the dates the oppositions in 2018 and 2035 would occur.

   2.3. Explain, why the difference appeared between the calculated and real dates of the opposition 2018. (Draw a figure that clearly demonstrates your explanation.)

   2.4. In which of the oppositions, 2018 or 2035 is Mars brightest? (The answer must be justified by drawing a figure).

3. **Sunset at Colombo.** The sunset picture was taken on September 30, 2018, from the seafront in the center of Colombo. The height of the camera above sea level was approximately 6.5 m. Calculate with the highest possible reasonable accuracy:

   3.1. at what time (use Sri Lanka time) the picture was taken.

   3.2. after what time after the moment of this picture will civil twilight end?

   3.3. Draw the position of the Sun seen at this moment from Adams Pk. (see the map) located to the East of Colombo (if clouds do not obstruct the observation).

4. **Colombo. Geostationary satellite.**

   4.1. At what minimum zenith distance can a geostationary satellite be observed from Colombo? Suppose that such a satellite is observed as a 2^m star in the night sky.

   4.2. How long during a day (24^h) can we see this satellite with the naked eye (in a clear sky)?

   4.3. Estimate the size of the satellite, considering it a polished metallic sphere.

5. **Oort cloud.** It is currently considered that the source of long-periodic and non-periodic comets is the outer Oort cloud, the inner and outer radii of which are estimated as 0.2 and 0.8 light years, respectively. Comet bodies in this cloud move erratically and sometimes collide with each other. As a result, every century, people of the Earth observe from 10 to 20 bright comets coming into the internal regions of the Solar System. The average size of the nuclei of such comets is about 2-3 kilometers. Roughly estimate (in order of magnitude) the total number of such comet bodies in the outer Oort cloud, the average distance between them, and their total mass. Compare the results with distances and masses of bodies in our Solar system.

Theoretical round. Problems to solve

1. **Distance to galaxy.** By research of a supernova explosion in a distant galaxy, two scientists noticed that the hydrogen line Hβ, which was observed in its spectrum, exactly matched the laboratory line Hα. However, these scientists hold different views on the numerical value of the Hubble parameter. Using different values that differ from each other by $\Delta H_0 = H_2 - H_1 = 14$ km/s/Mpc, they obtained different values for the maximum absolute magnitude of the observed supernova: $M_1 = -19{,}02^m$ and $M_2 = -18{,}64^m$. Find, according to the point of view of the scientists, the redshift of this distant galaxy and the distance to it.

2. **Martian observations.** In July this year, within one day, two unique astronomical phenomena occurred. In the morning of July 27, Mars came into a great opposition (see the attached ephemeris), and in the evening, the inhabitants of the Earth (those lucky with the weather and geographical location) observed a long lunar eclipse. But the approachment of the Earth and Mars is also a good time for Martian astronomers to study the Earth and the Moon. The Martian Space Agency planned two expeditions to the near-Mars piloted orbital station to observe:

   2.1. transit of the Earth across the disk of the Sun (it is assumed that the entire disk of the Earth must pass at least along the edge of the Sun) to study the atmosphere of the Earth;

   2.2. transit of the Moon across the disk of the Earth (it is assumed that the entire disk of the Moon must pass over the disk of the Earth) to study the lunar atmosphere.

   For each of these observations, determine in which constellation the objects will be observed from Mars, whether the orbital expedition is feasible (write "**Yes**" or "**No**" in English), and if so, find the minimum orbital period of Martian orbital station of the expedition, and if not, prove it by making the necessary calculations and drawings.

3. **Sunset at Colombo.** The sunset picture was taken on September 30, 2018, from the seafront in the center of Colombo. The height of the camera above sea level was approximately 6.5 m. Calculate with the highest possible reasonable accuracy:

   3.1. at what time (use Sri Lanka time) the picture was taken.

   3.2. after what time after the moment of this picture will civil twilight end?

   3.3. Draw the position of the Sun seen at this moment from Adams Pk. (see the map) located to the East of Colombo (if clouds do not obstruct the observation).

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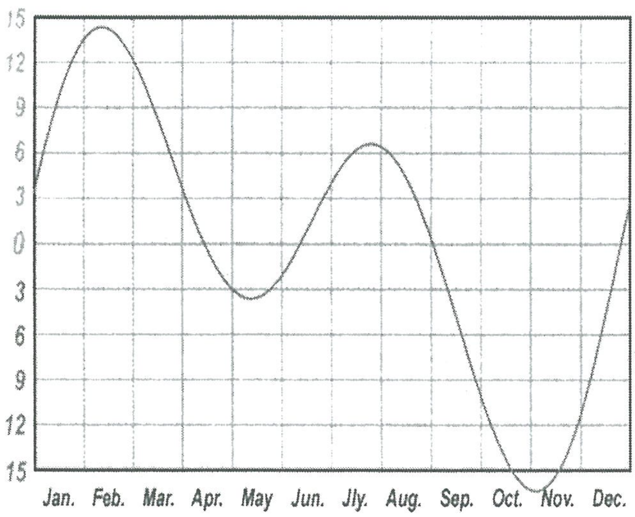
Элементы орбит и физические характеристики Солнца, планет, некоторых карликовых планет и Луны

Parameters of orbits and physical characteristics of Sun, planets, some dwarf planets and Moon

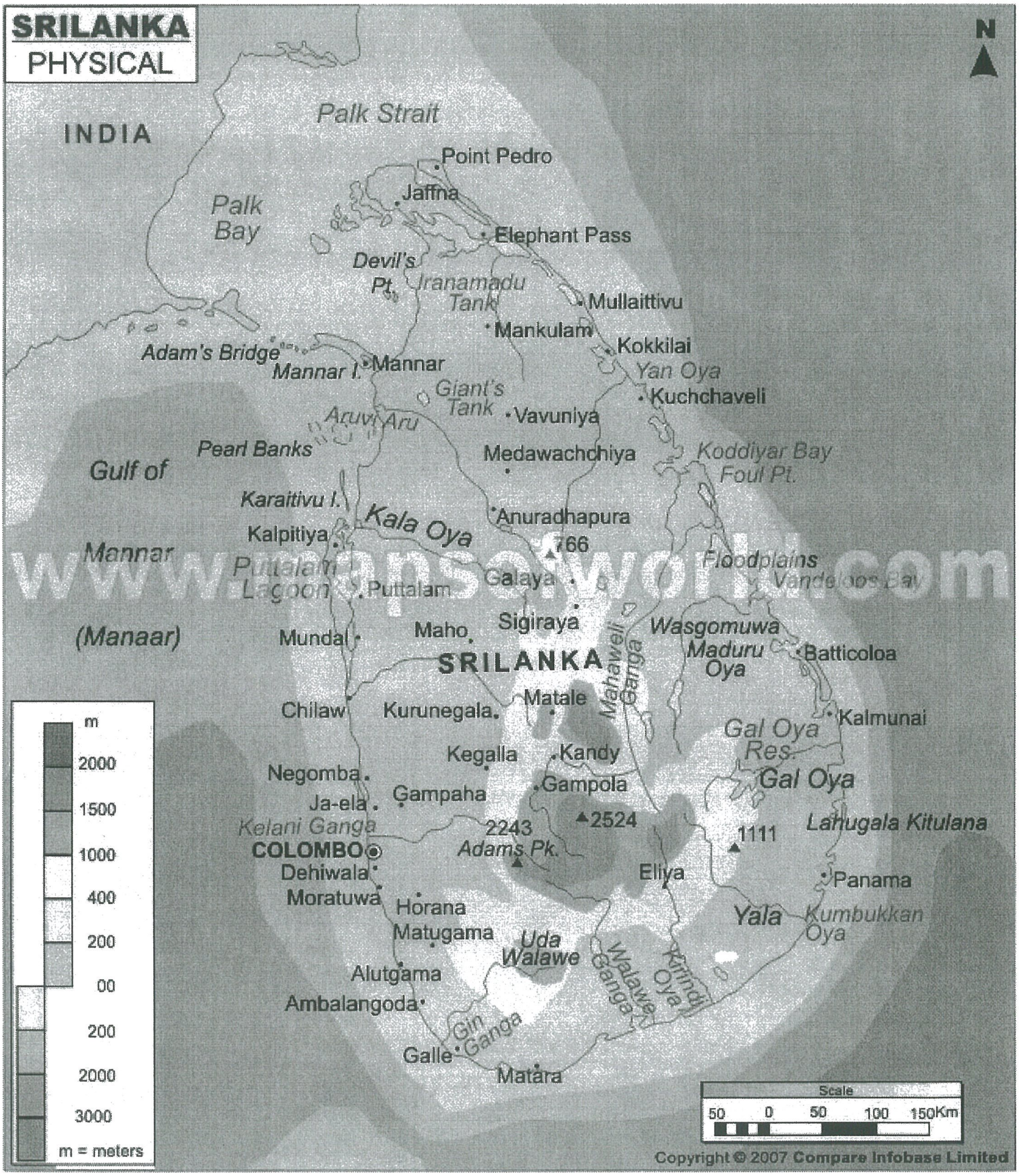
Небесное тело, планета / Body, planet	Среднее расстояние от центрального тела / Average distance to central body: в астр. ед. / in astr. units	в млн. км / in mln. km	Сидерический период обращения / Sidereal (or analogous) period: в тропич. годах / in tropical years	в средних сутках / in days	Эксцентриситет, e / Eccentricity, e	Экваториальн. диаметр, км / Equat. diameter, km	Масса, 10^{24} кг / Mass, 10^{24} kg	Средняя плотность, г/см³ / Av. density, g/cm³	Ускор. своб. пад. у пов., м/с² / Grav. acceler. at surf., m/s²	Макс. блеск, вид. с Земли **) / Max. magn. from Earth **)	Альбедо / Albedo
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	87,969	0 ,206	4 879	0,3302	5,43	3,70	$-2{,}2^m$	0,06
Венера Venus	0,723	108,2	0,615	224,701	0,007	12 104	4,8690	5,24	8,87	$-4{,}7^m$	0,78
Земля Earth	1,000	149,6	1,000	365,256	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	686,980	0,093	6 794	0,6419	3,94	3,71	$-2{,}0^m$	0,15
Церера Ceres	2,77	414	4,60	1 681	0,077	963	0,0009	2,16	0,27	$6{,}7^m$	0,09
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
Уран Uranus	19,191	2871,0	84,015	30 685,93	0,046	51 118	86,625	1,30	8,44	$5{,}5^m$	0,74
Нептун Neptune	30,071	4498,6	164,778	60 187,64	0,008	49 532	102,78	1,76	11,20	$7{,}8^m$	0,58
Плутон Pluto	39,482	5906,4	248,09	90 613	0,249	2 374	0,0130	1,86	0,61	$15{,}1^m$	0,6

**) Для внешних планет и Луны – в среднем противостоянии.
**) For outer planets and Moon – in mean opposition.



Equation of time **Уравнение времени**

Coordinates Координаты	Hotel Гостиница	Seafront in the center Набережная в центре
λ (E / в.д.)	79° 52′	79° 51′
φ (N / с.ш.)	07° 00′	06° 54′
Timezone Часовой пояс	UT+05:30	UT+05:30


SRILANKA
PHYSICAL
N
INDIA
Palk Strait
Palk Bay
Point Pedro
Jaffna
Elephant Pass
Devil's Pt.
Iranamadu Tank
Mullaittivu
Mankulam
Adam's Bridge
Mannar I.
Mannar
Kokkilai
Yan Oya
Kuchchaveli
Giant's Tank
Aruvi Aru
Vavuniya
Pearl Banks
Medawachchiya
Koddiyar Bay
Foul Pt.
Gulf of Mannar (Manaar)
Karaitivu I.
Kala Oya
Anuradhapura
Kalpitiya
766
Puttalam Lagoon
Puttalam
Galaya
Floodplains
Vandeloos Bay
Sigiraya
Mundal
Maho
Wasgomuwa
Maduru Oya
Batticoloa
SRILANKA
Mahaweli Ganga
Chilaw
Kurunegala
Matale
Kalmunai
Gal Oya Res.
Kegalla
Kandy
Negomba
Gampola
Gal Oya
Ja-ela
Gampaha
2524
Lahugala Kitulana
Kelani Ganga
2243
1111
COLOMBO
Adams Pk.
Eliya
Dehiwala
Panama
Moratuwa
Horana
Yala
Kumbukkan Oya
Matugama
Uda Walawe
Walawe Ganga
Kirindi Oya
Alutgama
Ambalangoda
Gin Ganga
Galle
Matara
m
2000
1500
1000
400
200
00
200
2000
3000
m = meters
Scale
50 0 50 100 150Km
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Sunset in Colombo 30. 09. 2018.

Заход Солнца в Коломбо 30. 09. 2018.

Round	Theo
Group	α β
язык / language	Czech
язык / anguag	English

Některé konstanty a vzorce / Some constants and formulae

Rychlost světla ve vakuu, c (m/s)	299 792 458	Speed of light in vacuum, c (m/s)
Gravitační konstanta, G ($N\cdot m^2/kg^2$)	$6.674\cdot 10^{-11}$	Constant of gravitation, G ($N\cdot m^2/kg^2$)
Sluneční konstanta, A (W/m^2)	1367	Solar constant, A (W/m^2)
střední hodnota / rozsah hodnot — Hubbleův parametr, H_0 (km/s/Mpc)	68 / 50-100	mean value / diapason of values — Hubble parameter, H_0 (km/s/Mpc)
Planckova konstanta, h (J·s)	$6.626\cdot 10^{-34}$	Planck constant, h (J·s)
Náboj elektronu, e (C)	$1.602\cdot 10^{-19}$	Charge of electron, e (C)
Hmotnost elektronu, m_e (kg)	$9.109\cdot 10^{-31}$	Mass of electron, m_e (kg)
Hmotnostní poměr protonu ku elektronu	1836.15	Proton-to-electron mass ratio
Faradayova konstanta, F (C/mol)	96 485	Faraday constant, F (C/mol)
Permeabilita vakua, μ_0 (H/m)	$1.257\cdot 10^{-6}$	Magnetic constant, μ_0 (H/m)
Molární plynová konstanta, R (J/mol/K)	8.314	Universal gas constant, R (J/mol/K)
Boltzmannova konstanta, k (J/K)	$1.381\cdot 10^{-23}$	Boltzmann constant, k (J/K)
Stefan-Boltzmannova konstanta, σ ($W/m^2/K^4$)	$5.670\cdot 10^{-8}$	Stefan-Boltzmann constant, σ ($W/m^2/K^4$)
Wienova konstanta, b (m·K)	0.002897	Wien's displacement constant, b (m·K)
Laboratorní vlnová délka Hα (Å)	6563	Laboratory wavelength of Hα (Å)
Laboratorní vlnová délka Hβ (Å)	4861	Laboratory wavelength of Hβ (Å)
Tropický rok, T (dny)	365.242199	Tropical year length, T (days)
Siderický rok, T (dny)	365.25636	Sidereal year length, T (days)
Anomalistický rok, T (dny)	365.259636	Anomalistic year length, T (days)
Oběžná uzlová doba měsíční dráhy (roky)	-18.6	Nodal period of lunar orbit (years)
Normální atmosférický tlak (Pa)	101 325	Standard atmosphere (Pa)
Extinkce viditelného světla v zenitu vlivem zemské atmosféry (minimum)	19%, 0.23^m	Visible light extinction by the terrestrial atmosphere in zenith (minimum)
Výška homogenní atmosféry (m)	7991	Height of homogeneous atmosphere (m)
Index lomu vody při 20°C, n	1.334	Refractive index of water for 20°C, n
Moment setrvačnosti tuhé koule	$I = \frac{2}{5} MR^2$	Moment of inertia of a solid ball
Moment setrvačnosti kulové slupky	$I = \frac{2}{3} MR^2$	Moment of inertia of sphere
Objem koule	$V = \frac{4}{3} \pi R^3$	Volume of a ball
Povrch koule	$S = 4\pi R^2$	Area of sphere
π	3.14159265	π
e	2.71828183	e
Zlatý řez, φ	1.61803399	Golden ratio, φ

Geocentric Ephemeris for Mars 2018 Геоцентрические эфемериды Марса

00:00 UTC (Coordinated Universal Time)

Date (0 UT)	Apparent R.A. h m s	Apparent Declination ° ' "	Distance to Earth a.u.	Distance to Sun a.u.	App. Mag.	Ang. Diam. "	Phase Illum	Phase Angle °	S.E. Long °	S.E. Lat °	P.A. Axis °	Ls °	Solar Elong °	Events
Jul 21	20 39 26.38	-24 52 22.4	0.39251	1.40447	-2^{m}.6	23.8	0.996	7.1	122.2	-12.0	4.8	215.3	170.2W	
Jul 22	20 38 23.97	-24 58 44.6	0.39112	1.40370	-2^{m}.6	23.9	0.997	6.5	113.3	-11.8	4.9	215.9	171.0W	
Jul 23	20 37 20.16	-25 05 00.3	0.38987	1.40295	-2^{m}.6	24.0	0.997	5.9	104.4	-11.7	5.1	216.6	171.8W	
Jul 24	20 36 15.10	-25 11 08.7	0.38876	1.40221	-2^{m}.6	24.1	0.998	5.4	95.6	-11.6	5.3	217.2	172.5W	
Jul 25	20 35 08.97	-25 17 08.7	0.38779	1.40148	-2^{m}.6	24.1	0.998	5.0	86.7	-11.5	5.4	217.8	173.0W	
Jul 26	20 34 01.95	-25 22 59.4	0.38697	1.40076	-2^{m}.6	24.2	0.998	4.8	77.9	-11.3	5.6	218.4	173.4W	
Jul 27	20 32 54.20	-25 28 39.9	0.38628	1.40006	-2^{m}.6	24.2	0.998	4.7	69.0	-11.2	5.8	219.0	173.5W	Opp. 05:12
Jul 28	20 31 45.92	-25 34 09.4	0.38574	1.39936	-2^{m}.6	24.3	0.998	4.8	60.1	-11.1	5.9	219.6	173.4W	
Jul 29	20 30 37.29	-25 39 27.0	0.38534	1.39868	-2^{m}.6	24.3	0.998	5.0	51.3	-11.0	6.1	220.3	173.1E	
Jul 30	20 29 28.49	-25 44 31.9	0.38509	1.39801	-2^{m}.6	24.3	0.998	5.3	42.4	-10.9	6.3	220.9	172.6E	
Jul 31	20 28 19.72	-25 49 23.5	0.38497	1.39735	-2^{m}.6	24.3	0.997	5.8	33.6	-10.8	6.5	221.5	172.0E	
Aug 01	20 27 11.15	-25 54 00.9	0.38499	1.39671	-2^{m}.6	24.3	0.997	6.4	24.7	-10.7	6.6	222.1	171.2E	
Aug 02	20 26 02.99	-25 58 23.5	0.38516	1.39607	-2^{m}.6	24.3	0.996	7.0	15.9	-10.6	6.8	222.7	170.3E	

Geocentric Ephemeris for Moon 2018 Геоцентрические эфемериды Луны

00:00 UTC (Coordinated Universal Time)

Date (0 UT)	Apparent R.A. h m s	Apparent Declination ° ' "	Distance km	Hor. Par. "	Ang. Diam. "	Libration l °	Libration b °	Libration c °	Sun Colng °	P.A. Limb °	Phase Age days	Phase Illum	Solar Elong °	Lunar_Events
Jul 21	14 45 33.85	-10 28 52.9	391335	3361.9	1831.6	7.2	-6.8	17.3	6.9	288.7	7.9	0.622	103.9E	
Jul 22	15 34 34.18	-14 05 16.4	395867	3323.5	1810.6	6.6	-6.5	13.2	19.1	286.1	8.9	0.716	115.5E	
Jul 23	16 24 00.93	-17 00 35.1	399584	3292.5	1793.8	5.8	-5.8	8.5	31.3	282.7	9.9	0.800	126.8E	
Jul 24	17 14 03.93	-19 08 30.5	402446	3269.1	1781.0	4.7	-5.0	3.5	43.6	278.8	10.9	0.872	137.9E	
Jul 25	18 04 37.75	-20 24 11.6	404465	3252.8	1772.1	3.5	-3.9	358.3	55.8	274.6	11.9	0.929	148.9E	MAX.S 20:56
Jul 26	18 55 23.82	-20 44 45.6	405690	3243.0	1766.7	2.1	-2.7	353.1	67.9	270.2	12.9	0.970	159.9E	
Jul 27	19 45 56.00	-20 09 47.7	406184	3239.0	1764.5	0.7	-1.3	348.3	80.1	266.1	13.9	0.994	170.8E	FULL 20:22
Jul 28	20 35 48.32	-18 41 32.1	406002	3240.5	1765.2	-0.7	0.1	344.0	92.3	77.6	14.9	1.000	178.3W	
Jul 29	21 24 42.50	-16 24 37.9	405174	3247.1	1768.9	-2.1	1.5	340.4	104.5	77.1	15.9	0.988	167.4W	
Jul 30	22 12 32.88	-13 25 32.9	403692	3259.0	1775.4	-3.4	2.8	337.8	116.7	74.2	16.9	0.959	156.4W	
Jul 31	22 59 27.93	-09 51 53.4	401527	3276.6	1785.0	-4.6	4.1	336.1	128.9	72.0	17.9	0.912	145.4W	
Aug 01	23 45 49.28	-05 51 51.5	398645	3300.3	1798.0	-5.6	5.1	335.5	141.1	70.4	18.9	0.849	134.2W	
Aug 02	00 32 09.52	-01 34 03.1	395034	3330.5	1814.4	-6.4	6.0	336.0	153.3	69.7	19.9	0.772	122.8W	

Geocentric Ephemeris for Sun 2018 Геоцентрические эфемериды Солнца

00:00 UTC (Coordinated Universal Time)

♈ Mar 20 16:15 ♋ Jun 21 10:07 ♎ Sep 23 01:54 ♑ Dec 21 22:23

Date (0 UT)	JD (2450000+)	App. GST (0 UT) h m s	Equation of Time m s	Apparent R.A. h m s	Apparent Declination ° ' "	Distance a.u.	Ang. Diam. "	Hel. Long °	Hel. Lat °	P.A. Axis °
Jul 21	8320.5	19:54:51.6	06:24.2	08 01 15.05	+20 30 58.9	1.016107	1888.8	212.6	4.9	6.2
Jul 22	8321.5	19:58:48.2	06:27.0	08 05 14.36	+20 19 18.9	1.016025	1889.0	199.4	5.0	6.6
Jul 23	8322.5	20:02:44.7	06:29.1	08 09 13.07	+20 07 18.6	1.015938	1889.1	186.1	5.0	7.0
Jul 24	8323.5	20:06:41.3	06:30.7	08 13 11.20	+19 54 58.0	1.015848	1889.3	172.9	5.1	7.5
Jul 25	8324.5	20:10:37.9	06:31.6	08 17 08.73	+19 42 17.7	1.015754	1889.5	159.7	5.2	7.9
Jul 26	8325.5	20:14:34.4	06:32.0	08 21 05.66	+19 29 17.7	1.015656	1889.7	146.4	5.3	8.3
Jul 27	8326.5	20:18:31.0	06:31.8	08 25 01.98	+19 15 58.4	1.015556	1889.9	133.2	5.4	8.7
Jul 28	8327.5	20:22:27.5	06:30.9	08 28 57.70	+19 02 20.0	1.015451	1890.1	120.0	5.5	9.1
Jul 29	8328.5	20:26:24.1	06:29.5	08 32 52.82	+18 48 22.8	1.015344	1890.3	106.7	5.5	9.5
Jul 30	8329.5	20:30:20.6	06:27.5	08 36 47.33	+18 34 07.0	1.015234	1890.5	93.5	5.6	10.0
Jul 31	8330.5	20:34:17.2	06:24.8	08 40 41.24	+18 19 33.1	1.015120	1890.7	80.3	5.7	10.4
Aug 01	8331.5	20:38:13.7	06:21.6	08 44 34.55	+18 04 41.1	1.015003	1890.9	67.1	5.8	10.8
Aug 02	8332.5	20:42:10.3	06:17.7	08 48 27.27	+17 49 31.3	1.014883	1891.1	53.8	5.8	11.2