Theoretical round. Problems to solve

Reminding. All the problems are compiled in such a way that the use of any language would not be required from the student when writing solutions. So writing texts is not allowed in solutions of the problems (neither in the native language, nor in one of the official languages of the IAO). Pay more attention to formulas, drawings and graphs. It is permitted to write a few keywords in English (for example, "Yes", "No", "Assume", "Answer", "Average", "Minimum", "Maximum", "Impossible situation", etc.), as well as terms contained in the accompanying tables and names of objects.

1(αγ). Supernova observation. The star Ypsilon Leonis was previously considered a candidate for supernovae. The White Bear-astronomer at the North Pole decided to observe a supposed this supernova outburst. He even equipped an observing platform made of ice at an altitude of 9 meters from the level of the Arctic Ocean.

1.1. Calculate and make a conclusion whether the Bear could have observed the outburst, if it had occurred. If "No", prove it by necessary formulae, calculations and maybe drawings. If "Yes", find the necessary conditions for the case, and also prove it by necessary formulae, calculations and maybe drawings. Remember yourself the dimensions and other necessary information about the animal. Consider the shape of the Earth spherical.

1.2. Accompany the solution with an artistic drawing of a happy (if he could observe) or sad (if he failed) Bear-observer on the observing platform at the North Pole.

2(αγ). Lost astronaut. Imagine that after the end of its work, the International Space Station was slightly reduced (to a mass of M = 300 ton) and decided to be sent to Mars. Somewhere in the middle of the way, one of the astronauts did not calculate the operating time when going into outer space and it turned out that the fuel tanks of the spacesuit were emptied at a distance of L = 140 m from the station, when its velocity relative to the station was zero. The total mass of the astronaut in an interplanetary spacesuit (with empty fuel tanks) is m = 180 kg. Estimate the time **t** after which the astronaut reaches the station due to gravitational attraction.

3(αγ). NGC of the Year. NGC 2022 is a miniature planetary nebula in the constellation of Orion. In the accompanying materials you can see 1×1 arcsec negative picture of the area with NGC 2022 in the central part (Hubble Space Telescope photo, 2019), as well as some data about the nebula.

3.1. To what distance should we approach this nebula so that it shines like the Sun at the Earth?

3.2. What would be the angular size of this object in that case?

Theoretical round. Problems to solve

-5(αβγ). Partial solar eclipse 2022. In 8 days, on October 25, partial solar eclipse will occur. The maximum phase of the eclipse will be observed in Siberia and will be 0.8623 at 16:01:20 local time or 11:01:20 UT. In Matera, the maximum phase 0.309 will be observed at 12:29:15 local time or 10:29:15 UT. Geocentric angular diameter of the Moon's disk during the eclipse hours will be $d_☽ = 31'45''$. The extra-atmospheric magnitude of the Sun on October 25 will be equal to $m_⊙ = -27.98^m$.

4(αβγ). Partial solar eclipse 2022 in Siberia.

4.1. Give all the calculations (dimensions, angles) necessary for the correct completion of the next point (4.2.).

4.2. Draw what the picture of the eclipse will look like at the moment of the maximum phase from the point where the maximum phase will be observed. In the picture, draw important details, points and lines (for example, zenith, horizon, etc.). The “top” direction in your drawing should coincide with the “top” direction in the sky.

4.3. An artificial Earth satellite has been launched to observe this eclipse. Estimate the minimum possible orbital period of this satellite so that at some moment the eclipse becomes central to it.

4.4. Calculate and show with the help of numerical values, whether the eclipse visible in the previous paragraph will be total (write in English «Total») or annular (write in English «Annular»).

5(αβγ). Partial solar eclipse 2022 in Matera.

5.1. Estimate altitude of the Sun in Matera at the time of the maximum (for Matera) phase of the eclipse. Accompany the solution with the necessary drawings.

5.2. Calculate the magnitude of the Sun m_{ecl} visible in the Matera at the moment of the maximum (for Matera) phase of the eclipse (in the case of a completely clear sky). Accompany the solution with the necessary drawings.

6(αβγ). Archimedes' mirrors. *The problem is related to the location of the Olympiad. Syracuse and Matera are located in the same geographical region.*

There is a legend that during the siege of Syracuse (214–212 BC) Archimedes destroyed enemy ships by directing reflected light from many mirrors at them. As soon as the enemy ship approached a distance of ½ of the ancient Greek stadion, the warriors, using large flat bronze mirrors, directed reflected sunlight at it and as soon as this light was concentrated in a circle with a diameter of 1 pechys, the ship ignited.

We will assume that a wooden ship could ignite when the spontaneous combustion temperature of the tree was exceeded (about 400°C for hardwoods) in the said circle with a diameter of 1 pechys. According to modern researchers, the reflectivity of bronze mirrors in ancient Greece was about 40%. Also, since the legend spoke of mirrors of such a maximum size that 1 warrior could hold, the size of the mirrors was probably about 1–1.5 meters.

In current units, 1 ancient Greek stadion (στάδιον) is equal to 184.9 m, and 1 pechys (πῆχυς) is 462 mm.

6.1. Estimate the light from how many mirrors it was necessary to direct at the enemy ship so that it caught fire.

6.2. What should be the minimum diameter of such mirrors?

Theoretical round. Problems to solve

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7(βγ). Planet. *The problem is devoted to the 90th anniversary of the Chandrasekar limit discovery.*
A white dwarf with a magnitude of $m_{WD} = 16.4^m$ and a mass equal to one third of the Chandrasekhar limit was discovered in the neighborhood of Canopus. A planet similar to the Earth (which also has a similar atmosphere and climate) orbits this white dwarf. Calculate (estimate)

7.1. the sidereal period of this planet

7.2. and the angular size of the white dwarf visible from the planet.

In the accompanying materials you can find mass-radius dependence for white dwarfs.

8(βγ). Vega. Estimate the lifetime of the Vega star on the main sequence. It is considered that it will leave the main sequence after it has exhausted $\eta = 20\%$ of the hydrogen, which it originally consisted of. The mass defect in the fusion of four nuclei of hydrogen atoms into one nucleus of a helium atom is $\Delta m = 4.7 \cdot 10^{-29}$ kg.

9(βγ). Space yacht. Year 2217. A space tourist on a space yacht has a flight from the Earth to Mars. After orbiting the Sun in a circular orbit of radius 1 au the yacht opens a solar sail and so enters the Hohmann-Zander orbit to Mars. Estimate:

9.1. the area **S**

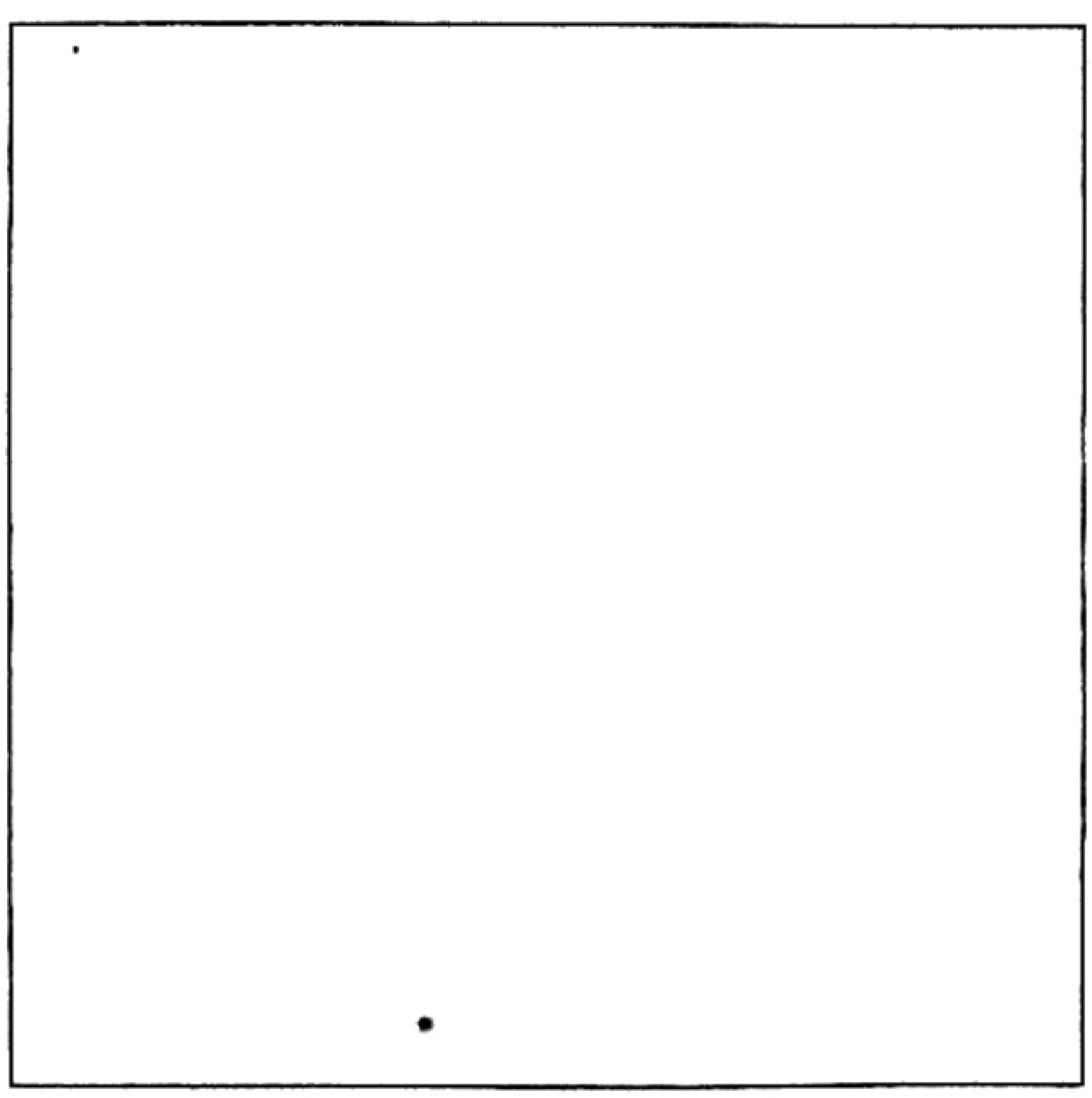
9.2. possible thickness **d**

of the opened part of the sail. Consider of the sail as a mirror, and the orbits of Earth and Mars as circular. The weight of the yacht together with the sail is **m** = 12 tons.

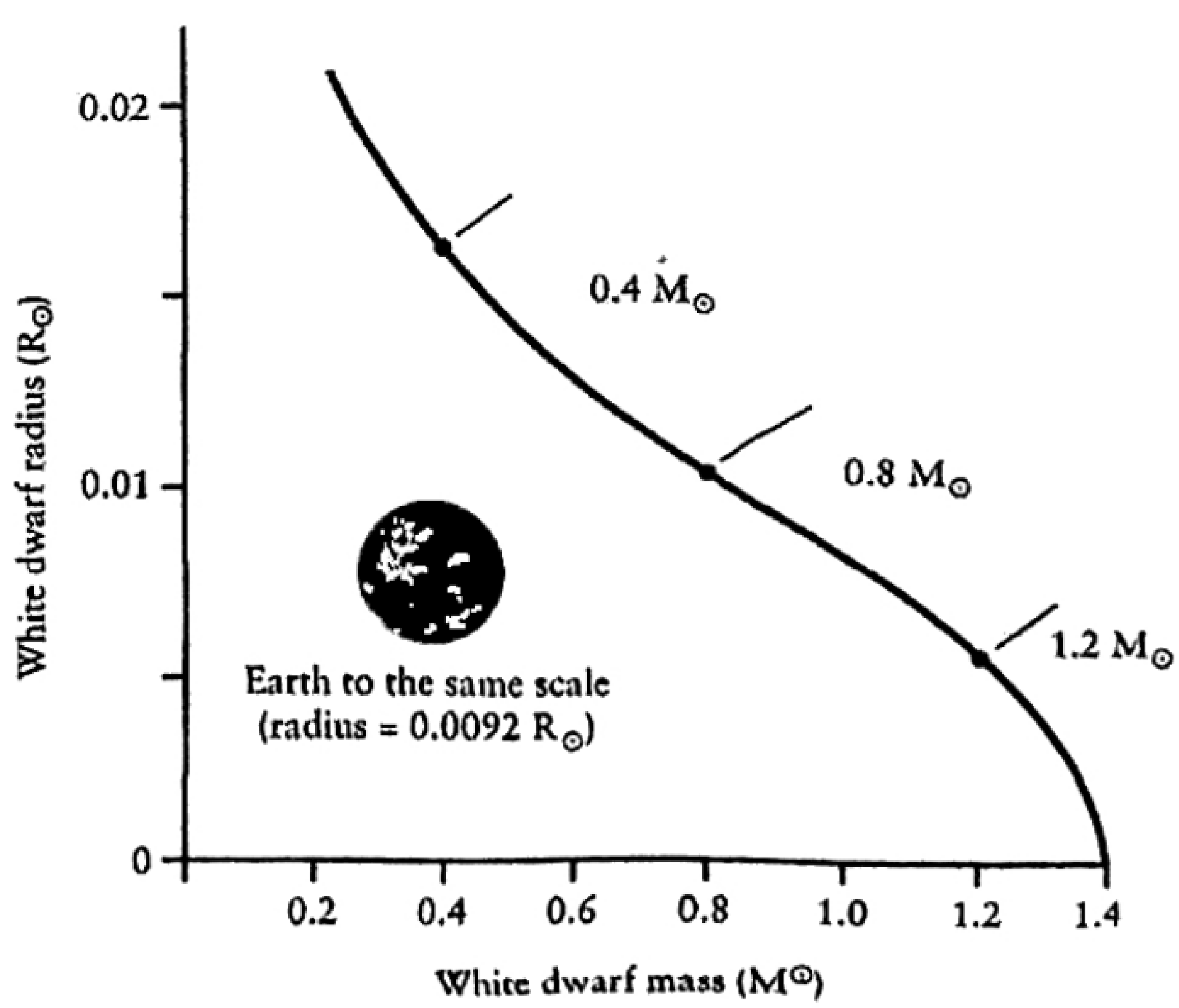
Данные о некоторых звёздах и объектах | Data of some stars and objects

			R.A.	DEC	p	Зв.вел. Mag.	Температура Temperature	Масса Mass
Солнце	Sun	Θ	$0^h - 24^h$	–23°26' – +23°26'	8″.794	$-26^m.74$	5777 K	1 M☉
Сириус	Sirius	α CMa A B	$06^h\ 45^m\ 09^s$	–16° 42' 58"	0″.379	$-1^m.47$ $8^m.44$	9940 K 25200 K	2.06 M☉ 1.02 M☉
Канопус	Canopus	α Car	$06^h\ 23^m\ 57^s$	–52° 41' 45"	0″.011	$-0^m.74$	7400 K	10 M☉
Толиман	Toliman (Rigel Kent)	α Cen A B	$14^h\ 39^m\ 36^s$	–60° 50' 07"	0″.747	$-0^m.01$ $1^m.33$	5810 K 5260 K	1.11 M☉ 0.93 M☉
Вега	Vega	α Lyr	$18^h\ 36^m\ 56^s$	38° 47' 01"	0″.130	$0^m.03$	9600 K	2.14 M☉
Капелла	Capella	α Aur	$05^h\ 16^m\ 41^s$	45° 59' 53"	0″.076	$0^m.08$	4970 K 5730 K 3700 K ???? K	2.57 M☉ 2.48 M☉ 0.57 M☉ 0.53 M☉
Ригель	Rigel	β Ori	$05^h\ 14^m\ 32^s$	08° 12' 06"	0″.004	$0^m.12^v$	12100 K	21 M☉
Процион	Procyon	α CMi A B	$07^h\ 39^m\ 18^s$	05° 13' 30"	0″.286	$0^m.37$ $10^m.75$	6600 K 9700 K	1.50 M☉ 0.60 M☉
Ахернар	Achernar	α Eri	$01^h\ 37^m\ 43^s$	–57° 14' 12"	0″.023	$0^m.45$	$12\text{-}17 \cdot 10^3$ K	6.7 M☉
Бетельгейзе	Betelgeuse	α Ori	$05^h\ 55^m\ 10^s$	07° 24' 25"	0″.005	$0^m.5$	3590 K	11.6 M☉
Хадар	Hadar	β Cen	$14^h\ 03^m\ 49^s$	–60° 22' 23"	0″.008	$0^m.61^v$	25000 K	12.0 M☉ 10.6 M☉
Альтаир	Altair	α Aql	$19^h\ 50^m\ 47^s$	08° 52' 06"	0″.195	$0^m.77$	8000 K	1.7 M☉
υ Льва	υ Leonis	υ Leo	$11^h\ 36^m\ 57^s$	–00° 49' 26"	0″.018	$4^m.33$	4840 K	2.58 M☉
Проксима Центавра	Proxima Centauri	V645 Cen, α Cen C	$14^h\ 29^m\ 43^s$	–62° 40' 46"	0″.769	$11^m.06$	3040 K	0.123 M☉
NGC 2022	NGC 2022	Ori	$05^h\ 42^m\ 06^s$	09° 05' 12"	0″.00040	$11^m.6$		

NGC 2022



Белые карлики | White dwarfs



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 ($Н\cdot м^2/кг^2$)	$6.674\cdot10^{-11}$	Constant of gravitation, G ($N\cdot m^2/kg^2$)
Солнечная постоянная, A ($Вт/м^2$)	1367	Solar constant, A (W/m^2)
Параметр Хаббла, H_0 (км/с/МПк) — среднее значение	68	mean value — Hubble parameter, H_0 (km/s/Mpc)
диапазон значений	50-100	range of values
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, m_p/m_e	1836.15	Proton-to-electron mass ratio, m_p/m_e
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/К)	8.314	Universal gas constant, R (J/mol/K)
Постоянная Больцмана, k (Дж/К)	$1.381\cdot10^{-23}$	Boltzmann constant, k (J/K)
Постоянная Стефана-Больцмана, σ ($Вт/м^2/К^4$)	$5.670\cdot10^{-8}$	Stefan-Boltzmann constant, σ ($W/m^2/K^4$)
Константа смещения Вина, b (м·К)	0.002897	Wien's displacement constant, b (m·K)
Лабораторная длина волны **Hα** (Å)	6563	Laboratory wavelength of **Hα** (Å)
Лабораторная длина волны **Hβ** (Å)	4861	Laboratory wavelength of **Hβ** (Å)
Длина тропического года, T (сут)	365.242199	Tropical year length, T (days)
Длина сидерического года, T (сут)	365.25636	Sidereal year length, T (days)
Длина аномалистического года, T (сут)	365.259636	Anomalistic year length, T (days)
Период обращения узлов лунной орбиты (лет)	–18.6	Nodal period of lunar orbit (years)
Зависимость атмосферного давления от высоты	$P = P_0e^{-\mu gh/RT}$	Dependence of atmospheric pressure on height
Стандартная атмосфера, P_o (Па)	101 325	Standard atmosphere, P_o (Pa)
Высота однородной атмосферы (м)	7991	Height of homogeneous atmosphere (m)
Ослабление видимого света слоем 1 атмосферы (минимально)	19%, 0.23^m	Visible light extinction by the terrestrial atmosphere in zenith (minimum)
Показатель преломления воздуха (1 атм., 0°C), n	1.0002926	Refractive index of air (1 atm., 0°C), n
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
Момент инерции сферы	$I = {}^2/_3\, MR^2$	Moment of inertia of spherical shell
Объём шара	$V = {}^4/_3\, \pi R^3$	Volume of a sphere
Площадь сферы	$S = 4\pi R^2$	Surface of sphere
π	3.14159265	**π**
e	2.71828183	e
Золотое сечение, φ	1.61803399	Golden ratio, φ
Формула рефракции в земной атмосфере для зенитных расстояний z' < 80°)	$\rho \approx \kappa\frac{P}{T}\tan z'$	Terrestrial atmospheric refraction formula for zenith distances z' < 80°
Коэффициент рефракции — κ (arcsec·K/Па)	0.1623	κ (arcsec·K/Pa) — Coefficient of refraction
k_0 (для 273 K, 760 мм.рт.ст.)	60.2"	k_0 (for 273 K, 760 mmHg)