Problem 1: «So different friction». Marking scheme

No.	Answers	points
1.1.1	Numerical answer for μ_1 [0,24-0,26]	1,5
1.1.2	Stated that μ_2 does not exist	1,5
1.1.3	Numerical answer for μ_3 [1,00-1,08]	1,5
1.1.4	Answer for α_{max} [79° – 80°]	4
1.2.1	Numerical answer for breaking distance (172-178) cm	5
1.2.2	Estimate of error from finite radius of cylindrical surface ≈ 3 %	0,5
1.3.1	Stated that the second tourist can cross via the log	3
1.3.2	Formula for the coordinate x of the first tourist, at which the log starts to slip $x=\left[(2M+m)\frac{\mu d-h}{\mu d+h}-m\right]\frac{d}{2M}$	1
1.3.3	Numerical value of x (1,85-1,89) m	1
1.3.4	Estimate for curvature radius of the log (formula) $R=\frac{Em^2}{2\pi(M+m)g\rho^2 d(d^2+h^2)}$	3
1.3.5	Curvature radius of the log – numerical answer 100 m – 400 m	2
1.3.6	Answer 1	1
	Total	25

Problem 2: «To the Sun!» Marking scheme

No.	Answer	points
2.1.1	Formula for the parameter $p = \dfrac{2r(R_E + h)}{r + R_E + h}$	0,5
2.1.2	Numerical value of parameter (11300-11700) km	0,5
2.1.3	Formula for the eccentricity $\varepsilon = \dfrac{r - R_E - h}{r + R_E + h}$	0,5
2.1.4	Numerical value of eccentricity (0,7-0,75)	0,5
2.1.5	Numerical value of energies fraction $\lvert E_0/E_1 \rvert$ (5,3-5,6)	2
2.2.1	Numerical value of velocity increase (1,4 – 1,6) km/s	2
2.2.2	Final mass of the ship fraction (51%-53%)	2
2.3.1	Answer: summer	0,5
2.3.2	Answer: noon	0,5
2.3.3	Numerical value of v_A (2,7-2,9) km/s	2
2.3.4	Численное значение v_2 (27,5-30) km/s	3
2.4.1	Part of the ship mass Δm_2, which should be detached (19 %-23%)	3
2.4.2	Mass of the part that will arrive to the Sun (1%-3%)	2
2.5.1	Formula for the time of movement $t = \dfrac{1}{2}\left(\dfrac{r_A + R_s}{r_A + r_P}\right)^{3/2} T_0$	2
2.5.2	Answer for the time (65-70) days	2
2.6.1	Maximum angle the velocity of the ship can be turned ($3° - 5°$)	5
2.6.2	Stated that gravitational maneuver cannot significantly change the mass that can arrive to the Sun (Answer: NO)	2
	Total	30

Problem 3: «PLANETARY NEBULA». Marking scheme

No.	Answer	points
3.1	Formula for Stefan-Boltzmann constant $\sigma = \frac{2\pi^5}{15}\frac{k^4}{c^2h^3}$	2
3.2	Formula for the temperature as a function of r: $\frac{T(r)}{T_0} \approx \sqrt{\frac{r_0}{r}}$	2
3.3	Formula for energy levels of hydrogen atom $E_n = -\frac{m_e e^4}{8\varepsilon_0^2 h^2}\cdot\frac{1}{n^2}$	2
3.4	Numerical value of minimal photon energy [13.5; 13.7] eV	1
3.5.1	Energy level number with the largest number of hydrogen atoms (n=1)	1
3.5.2	Fraction of atoms in excited states ≈ 0	1
3.6	Numerical value of the fraction of photons (17% - 23%)	2
3.7	Numerical value of mean free path of photons $[1.5;\ 1.9]\cdot\ 10^{13}$ cm	2
3.8	Stated that almost all photons are reprocessed (> 99%)	2
3.9	Correct relations between ΔN_{12}, ΔN_B и ΔN (1:1:1)	6
3.10.1	Planckian (thermal) background in spectrum	1
3.10.2	The spectrum is cut at frequencies larger than ionization threshold	2
3.10.3	The line corresponding frequency ν_{21} in spectrum	1
3.10.4	Other spectral lines corresponding to hydrogen energy levels differences	1
3.11.1	Equation for T_x (from ratio of ν_{21} line energy and thermal background energy) $0{,}1 = \frac{1{,}5z(2z+1)^2 e^{-z/2}}{(z+1)^3 e^{+z/2} - (1{,}5z+1)^3}$, $z \approx \frac{78840\,K}{T_0}$.	6
3.11.2	Numerical answer for temperature (18000 - 20500 K)	4
3.12.1	Numerical answer for l_1 $[1.4;\ 1.8]\cdot\ 10^{15}$ cm	3
3.12.2	Numerical answer for l_2 $[1.6;\ 2.0]\cdot\ 10^{15}$ cm	3
3.12.3	Numerical answer for l_3 $[1.7;\ 2.1]\cdot\ 10^{15}$ cm	3
	Total	45