Theoretical round. Basic criteria. For work of Jury

Note. Jury members should evaluate the student's solutions in essence, and not by looking on formal existence the mentioned sentences or formulae. The formal presence of the mentioned positions in the text is not necessary to give the respective points. Points should be done if the following steps de facto use these positions. (For example, except the final conclusion, all the points in solution of problem 3 may be in only one common formula.)

Note. Jury members should elaborate more detailed criteria, and also create criteria for other correct ways of the student's solutions.

Note. Everywhere "formula" means "correct formula", "calculation" means "correct calculation", "picture" means "correct picture", etc., and in all cases: based on correct facts and intermediate formulae or calculations.

1. Parallax measurements.

Understanding that the parallax base (a) 1.379/0.379 = 3.64 times larger – 1 pt.
Using Kepler's III Law $(T_2/T_1)^2 = (a_2/a_1)^3$ – 1 pt.
Calculation minimal period $T_2 = T_1 \cdot (a_2/a_1)^{3/2} = T_1 \cdot (\pi_2/\pi_1)^{3/2}$ = 6.94 years – 1 pt.
Minor semi-axis $b = a(1-e^2)^{1/2}$ – 1 pt.
Calculation maximum major semi-axis $a_3 = b/(1-e^2)^{1/2}$ = 3.64 au / $(0.6519)^{1/2}$ = 4,51 au – 1 pt.
Formula and calculations $T_3 = T_1 \cdot (a_3/a_1)^{3/2} = T_1 \cdot 4.51^{3/2}$ = 9.57 years – 1,5 pt.
Correct full final answer (not two values but range): $6.94^Y \le T \le 9.57^Y$ – 1,5 pt.

2. Spacecraft.

Understanding that calculation of the density necessary – 2 pt.
Finding orbit period $T = 2\tau$ = 19.28 days – 0,5 pt.
Finding major semi-axis $a = ((1/\sin(\alpha_P/2) + 1/\sin(\alpha_A/2))/2)\ r$ = 42,6 r – 1 pt.
Relation between density and period – 1 pt.
Final formula (or analogous) $\rho = 3\pi((1/\sin(\alpha_P/2) + 1/\sin(\alpha_A/2))/2)^3/G(2\tau)^2$ – 1,5 pt.
Final calculation $\rho = 3{,}94 \cdot 10^3$ кг/м^3 – 1 pt.
Final answer "Mars" (based on value of the density) – 1 pt.

3. NGC of the Year.

For the solution, written in author's solutions:
Understanding the main limiting parameter for all situations is the diameter of the lens – 1,5 pt.
Difference in mag between NGC 2021 and the faintest star visible by humans – 1 pt.
Difference in fluxes of light $\exp_{10}(\Delta m/2.5) \approx 280$ – 1,5 pt.
Lens should be $N_1 = (\exp_{10}((12{,}1^m - 6^m)/2.5^m))^{1/2} \approx 17$ lager than human pupil – 1,5 pt.
Finding N_2 = 45 mm / 6 mm = 7,5 – 1 pt.
$N_2 < N_1$ – 0,5 pt.
Formal answer "No" for all the cases – 1 pt.
Note: there may be many analogous versions, other order of steps possible. For example, may be calculation the limiting lens diameter 17×6 mm ≈ 100 mm, etc.

Other types of solutions (alternative, not addition to author's solution, but instead):
If any other correct criteria were used for proving impossibility to observe NGC 2021 by any animal:
Correct final conclusion for each animal based on correct base – 0,5 pt.

4-5. Eclipse at the North Pole.

4.1. up to 4 points in total, number of points should be proportional to the part of progress in writing correct formulae and correct necessary calculations.

4.2. up to 2 points in total, including

exact correct size of the Sun – 0,5 pt,
exact correct size of the Moon – 0,5 pt,
exact correct displacement of lunar disk relative to solar disk – 0,5 pt,
quality of the picture – 0,5 pt.

4.3. up to 2 points in total, number of points should be proportional to the part of progress in writing correct formulae, correct necessary calculations, and the final result.

5.1. Artistic drawing – up to 2,5 points in total. including:
the Bear – up to 1 pt (depending on the quality of the picture),
photographic equipment – up to 0,5 pt (depending on the quality of the picture),
correct direction of the camera, approx. 23° to the horizon – 1 pt.

5.2. Up to 5,5 pt in total, including:
using solar constant, A = 1367 Вт/м^2 – 1 pt,
conclusion that the height of the Sun is equal to the declination of the Sun – 0,5 pt,
formula $\delta = \varepsilon \cdot \cos 12°$ – 0,5 pt,
calculation $\delta = 23.44° \cdot \cos 12° \approx 22.9°$ – 0,5 pt,
calculation of the area of visible ring relative to full solar disc$\cdot(\mathbf{d_0^2} - \mathbf{d_1^2})/\mathbf{d_0^2}$ – 1,5 pt,
final formula, calculations and result – 1,5 pt.

6. Closer to the stars.

Understanding the idea to compare closing to the stars and extinction by atmosphere – 2 pt.
Using value of one atmosphere (maybe approx.) – 1 pt.
Using value of extinction by the terrestrial atmosphere in zenith (maybe approx.) – 1 pt.
Intermediate formulae – up to 1 pt.
Intermediate calculations – up to 1 pt.
Final calculations and answer – 2 pt.

7. Variable star.

Calculation of speed of the star relative to the Earth $v_E = V_{orb}/c \times \cos\beta - v$ – up to 3,5 pt in total (including analyzing the sky map, correct using V_{orb}, correct using $\cos\beta$, correct direction of the speed of the Earth around the Sun, etc.)
Correct using Doppler effect – 1,5 pt.
Final correct calculations and answer – 2 pt.
Correct accuracy 1 second (not less ant more) – 1 pt.

Other solutions:

For any solution that does not take into account moving the Earth around the Sun – not more than 1,5 pt.

8. Alpha Centauri.

The distance to Alpha Centauri – 1 pt.
Finding the ratio of luminosities of Alpha Centauri and the Sun – 2 pt.
Using $L \sim R^2T^4$ – 1 pt.
Using $\rho \sim M/R^3$ – 1 pt.
Conclusion $\rho \sim MT^6/L^{3/2}$ – 1 pt.
Final calculations and result – 2 pt.

9. Dark matter.

Wien's law – 0,5 pt.
Formula and calculations for redshift – 1 pt.
Hubble's law – 0,5 pt.
Formula and calculations for the distance to the galaxies – 1 pt.
Relative velocity of the mutual motion of the galaxies – 1 pt.
Apparent distance between the galaxies – 1 pt.
Generalized Kepler's Third Law – 0,5 pt.
Finding the total mass of the galaxies – 0,5 pt.
Finding the mass of the Sun-like stars in the galaxies (through magnitudes) – 1 pt.
Finding the ratio between mass of the Sun-like stars in total mass – 0,5 pt.
Final result and answer – 0,5 pt.