Theoretical round

1. **Sizes and masses.** In the table given at a separate sheet enumerate in growing order (from 1 to 13) the size and the mass of each object: Milky Way Galaxy, Andromeda Galaxy, Neutron star, Electron, Mercury, The first satellite “Sputnik I”, Venus, Pluto, Proton, Red dwarf, Black cat, White (Polar) bear, the Sun.

2. **Umbra and penumbra.** As you know, on clear sunny days, objects usually give rise to umbras and penumbras. Nowadays, the angle of the ecliptic plane to the celestial equator is $\varepsilon_0 = 23°26.2'$ and is reduced by about $\upsilon = 0.78'$ per century. Calculate in what century begins the period or in what century the period has ended when from the exactly vertical column located in Ashulia
   2.1. umbra from the Sun
   2.2. penumbra from the Sun
   will disappear (or disappeared) at some sunny days of the year.
   Ashulia’s coordinates are 23°53.6' N, 90°19.8' E.
   Draw pictures explaining your solution.

3. **Star setting.** The Bengal Tiger likes to observe stars. According to his calculations, some star will rise today at 19^h45^m and will culminate at 21^h49^m. At what time yesterday did the star set? The refraction and horizon lowering can be disregarded. The solution has to include an artistic picture with an image of the Bengal Tiger-astronomer observing the star.

Problems 4–7 – see on the back.

4. Comet Lovejoy. The table below presents data for the comet C/2014 Q2 (Lovejoy), which this year was the brightest comet in our sky:

Discovery date	17 August 2014
Discovered by	Terry Lovejoy (Brisben, Australia)
Discovered with	20-cm Schmidt-Cassegrain telescope
Perihelion (q)	1.2904 au
Eccentricity	0.99811
Orbital period (P)	~9000 years
Inclination	80.301°
Last perihelion	30 January 2015
Minimum magnitude	$3.9^{\mathbf{m}}$
In constellation	Eridanus
Actual magnitude	$18.6^{\mathbf{m}}$
In constellation	Hercules

From these data, calculate in the easiest way, the approximate speed of the comet on January 30, 2015. The orbital speed of the Earth is $V_E \approx 29.8$ km/s.

5. Distance between galaxies. According to estimations of scientists, there are about 1800 galaxies in the cluster of galaxies in the constellation Coma Berenices, which show redshift of 0.023. The region in our sky covered by this cluster is about $9\times10°$. Estimate the average distance between the galaxies in this cluster. Draw a picture explaining your solution.

6. Cluster. Astronomers find a "star" which position in the Hertzsprung-Russell diagram is about $9^{\mathbf{m}}$ higher than the corresponding stars of the main sequence. Assuming the "star" was a cluster of stars similar to each other, estimate the number of stars in the cluster.

7. Photons. Radio- (operating wavelength is about 21 cm) and optical (operating in the light visible to the naked eye) telescopes have been used to study an astrophysical object. It was discovered that the energy fluxes from the object in the radio and optical frequencies were equal.

7.1. Which photons' number is the largest, radio or optical? (Write in English "**radio**" or "**optical**" respectively.) By how many times is it more?

7.2. What should be the size of the radio telescope to make its resolving power the same as that of the human eye?