II. First long problem - Zodiac IOAA – J – 2022 – 100 points

In their apparent motions, the Moon and the other large planets in our solar system do not stray far from the plane of the ecliptic. Their apparent trajectories described on the celestial sphere remain contained in a region that extends symmetrically on both sides of the ecliptic, having a total width of about 18º. In the drawing in figure 1, in the plane of the ecliptic, the heliocentric orbit of the Earth is shown, and in the drawing in figure 2, the equivalent apparent geocentric orbit of the Sun, in relation to the Earth, is shown.

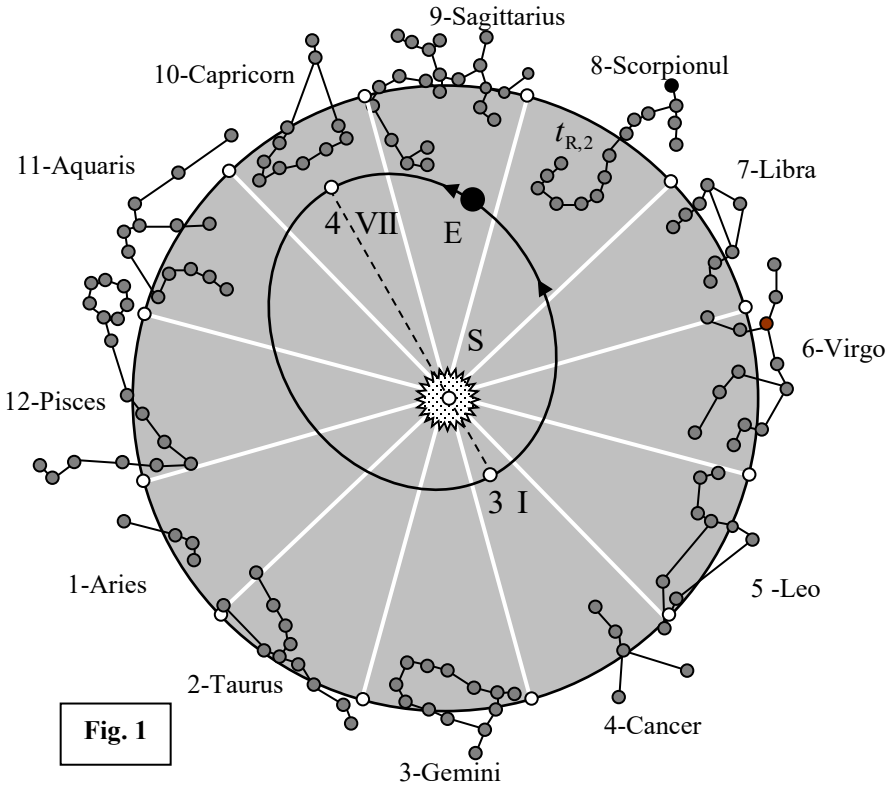
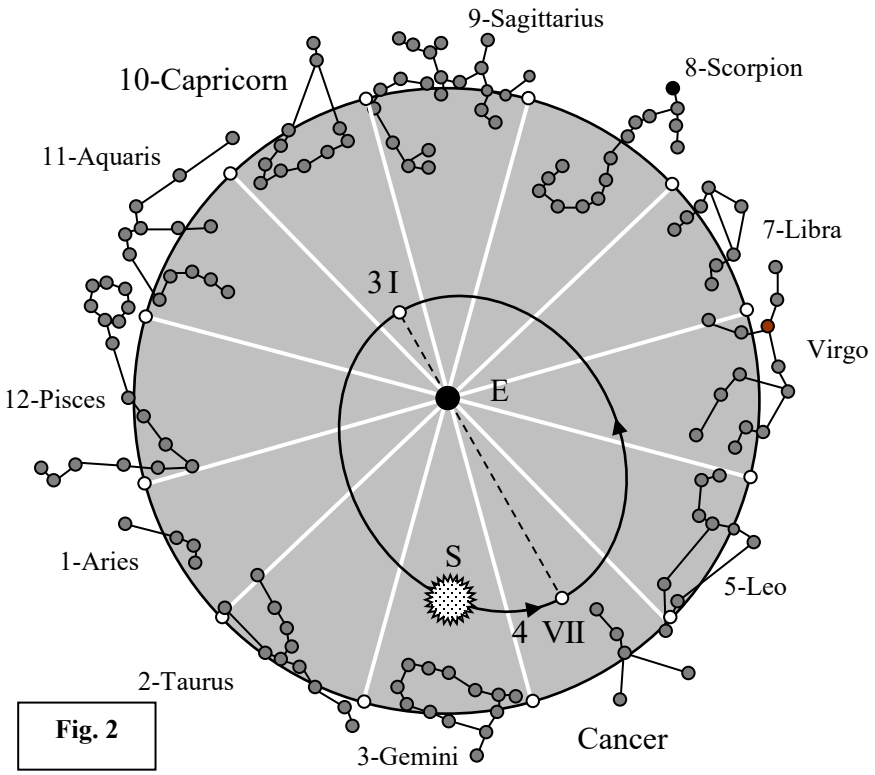

9-Sagittarius
10-Capricorn
8-Scorpionul
$t_{R,2}$
11-Aquaris
7-Libra
4 VII
E
S
6-Virgo
12-Pisces
3 I
1-Aries
5 -Leo
2-Taurus
4-Cancer
3-Gemini

Fig. 1


9-Sagittarius
10-Capricorn
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7-Libra
3 I
Virgo
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12-Pisces
1-Aries
S
5-Leo
4 VII
2-Taurus
3-Gemini
Cancer

Fig. 2

International Olympiad of Astronomy and Space Sciences
for Juniors
Romania– Câmpulung Moldovenesc
October 31 – November 7 2022
Theoretical Round

The time intervals of the evolution of the true Sun in each of the 12 constellations of the Zodiac are as follows: **1)** Aries, 21 III - 20 IV; **2)** Taurus, 21 IV - 20 V; **3)** Gemini, 21 V - 20 VI; **4)** Cancer, 21 VI - 22 VII; **5)** Leo, 23 VII - 22 VIII; **6)** Virgo, 23 VIII - 22 IX; **7)** Libra, 23 IX - 22 X; **8)** Scorpio, 23 X - 21 XI; **9)** Sagittarius, 22 XI - 21 XII; **10)** Capricorn, 22 XII - 21 I; **11)** Aquarius, 22 I - 19 II; **12)** Pisces, 20 II - 21 III.

The International Olympiad on Astronomy and Astrophysics for Juniors, Edition I, was to take place in SUCEAVA, in ROMANIA, on March 28 - April 3, 2020. The event, proposed by ROMANIA, was established at the International Olympiad of Astronomy and Astrophysics, 13th Edition, held in Hungary, on August 2-10, 2019.

But, given the known conditions, IOAA-jr, Edition I, is taking place in Romania, only now, in November 2022!

Hint: *All the tasks which require direct measurements on drawings will be performed on the pictures in page 5 (figure 1) and page 6 (figure 2). Both pages are part of answer-sheets*

A) (30 points) *Identify*:

1. the sign of the OIAA development, 13th Edition, Hungary, August 2 - 10, 2019;

2. the sign when the OIAA - J was to take place - Edition I, March 28 - April 3, 2020, Romania (Edition I, proposal);

3. the sign of the OIAA - J - Edition I, November, 2022.

B) (20 points) Each of the 3 specified Olympic events can be considered to have taken place on the day when the Sun, viewed from Earth, was in the middle of the angular range corresponding to each of the 3 signs.

1. *Determine* the time interval between any two of these three events:

$$\Delta t_{\mathrm{H-R,1}};\ \Delta t_{\mathrm{R,1-R,2}};\ \Delta t_{\mathrm{H-R,2}}.$$

2. *Estimate*, by direct measurements on the drawing, by means of a protractor, the value of the angle between the position vector of the Earth, in relation to the Sun, corresponding to each of the three specified moments, ie the directions of the vectors $\vec{r}_{\mathrm{H}}$, $\vec{r}_{\mathrm{R,1}}$ and respectively $\vec{r}_{\mathrm{R,2}}$, and the direction of the apse line, Aph – Ph, ie the angles α_{H}, $\alpha_{\mathrm{R,1}}$ and respectively $\alpha_{\mathrm{R,2}}$.

C) (20 points) *Determine* the area of the surface described by the position vector of the center of the Earth, $\vec{r}$, in relation to the center of the Sun:

1. from position $\vec{r}_{\mathrm{Hungry}}$ to position $\vec{r}_{\mathrm{Romania,\,1}}$;

2. from position $\vec{r}_{\mathrm{Romania,\,1}}$ to position $\vec{r}_{\mathrm{Romania,\,2}}$;

3. from position $\vec{r}_{\mathrm{Hungry}}$ to position $\vec{r}_{\mathrm{Romania,\,2}}$.

D) (30 points) *Determine*:

1. the distance between the Earth and the Sun, on the day when in Suceava, in 2020, the IOAA for Juniors, Edition I should have taken place, $r_{R,1}$, if, for the ellipse representing the Earth's orbit around the Sun, the following are known: semimajor axis, $a = 149597500$ km and semiminor axis, $b = 149\,580\,670$ km;

2. the acceleration of the center of the Earth, on the day when in Suceava, in 2020, the IOAA for Juniors should have taken place, $a_{E,1}$, and compared with the gravitational acceleration in the gravitational field of the Sun, corresponding to the distance $r_{R,1}$ from the center of the Sun, $g_{S,1}$;

3. the components of the speed of the center of the Earth, $\vec{v}_{R,1}$, parallel to the major axis of the ellipse and respectively perpendicular to the major axis of the ellipse, in the days of the International Olympiad in Romania, $v_{//}$ and respectively $v_{\perp}$.

It is known that the angular momentum of the Earth in relation to the center of the Sun and the total mechanical energy of the Earth-Sun system are given by the expressions:

$$L = M_E b \cdot \sqrt{\frac{GM_S}{a}}; \qquad E = -G\frac{M_E M_S}{2a}.$$

It is given: gravitational attraction constant, $G = 6.67 \cdot 10^{-11}\ Nm^2\,kg^{-2}$ mass of the Sun, $M_S = 1.989 \cdot 10^{30}\ kg$, and period of Earth's revolution is *T=365.256 days.*

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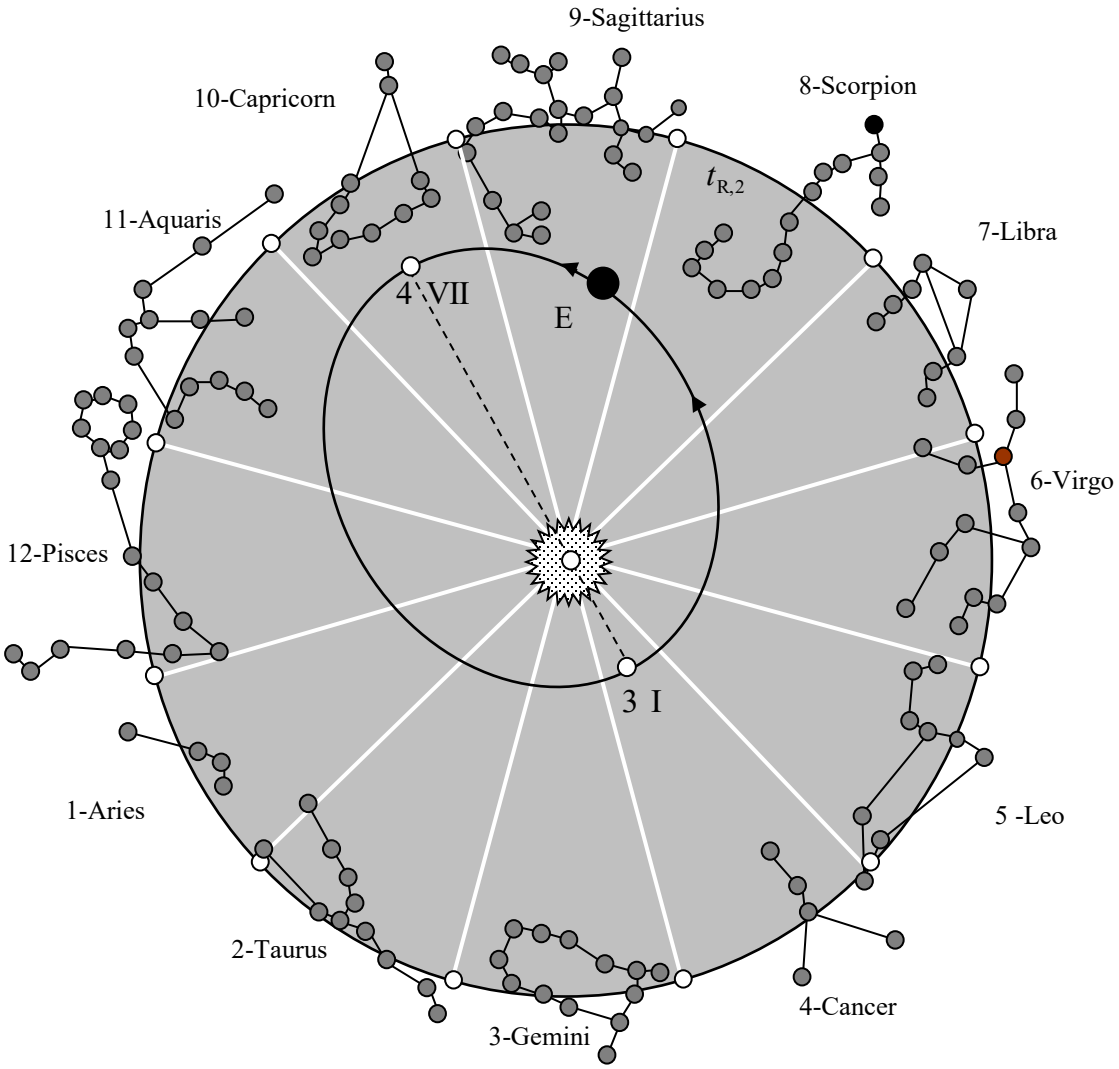

Figure 1, reproduced in enlarged format!
This image will be worked on and will be handed in with the competition sheets!

Student ID.....

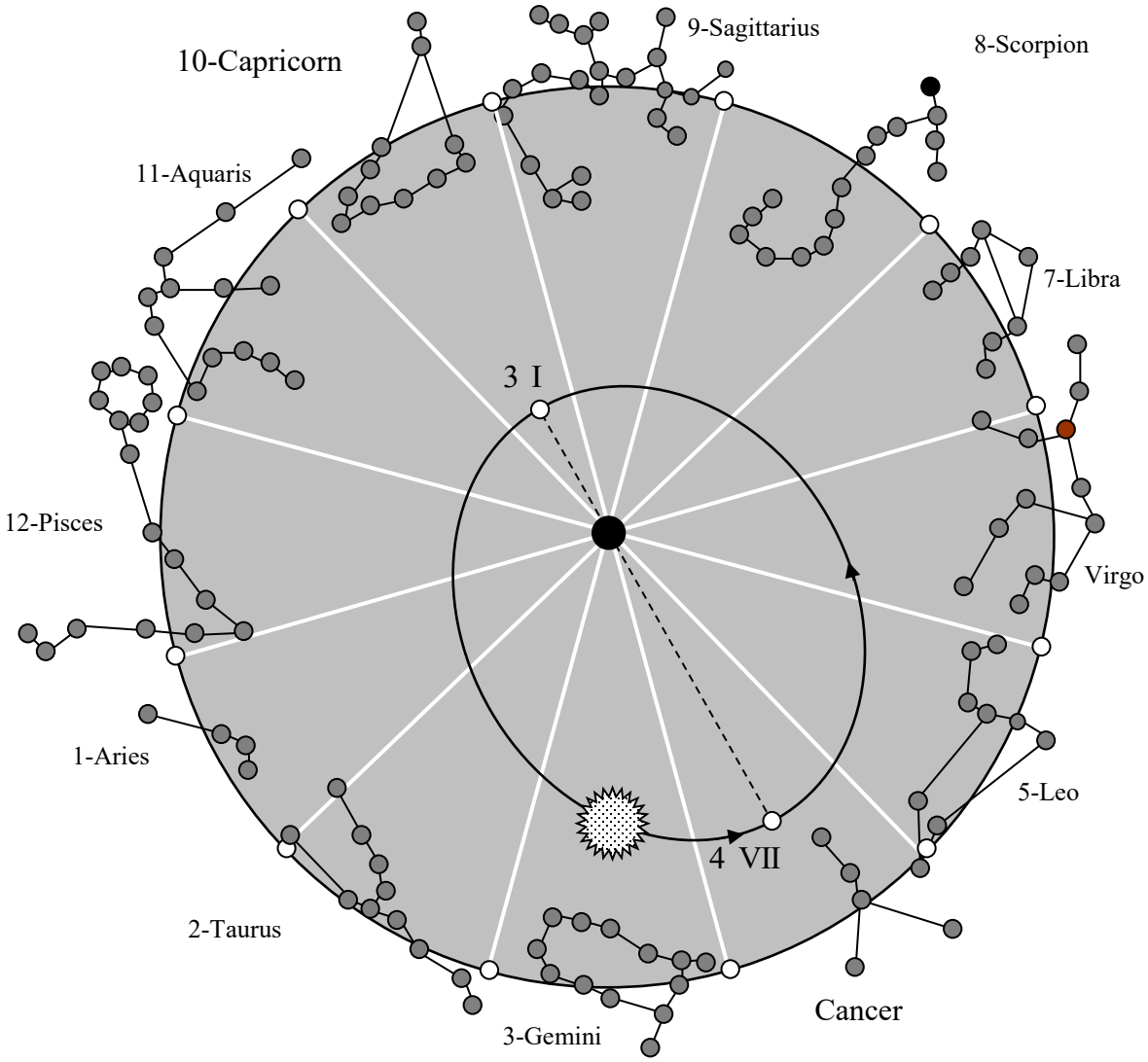

Figure 2, reproduced in enlarged format!
This image will be worked on and will be handed in with the competition sheets!