For translation only. **Practical round. Problems to solve**

Note for translators: ***Black colour – for both α and β.***
Red colour – only for Group α.
Blue colour – only for Group β.
Not allowed to put parts for Group α into envelopes for Group β and opposite.

6. The Asteroid 2110GD37.

You are provided with: scissors, thread, compass, protractor, ruler.

If the actual trajectory of Asteroid 2010GD37 remains the same, then in December 2019, the Asteroid will seriously threaten the Earth.

In case of danger, the specialists consider launching a projectile, from an artificial satellite of the Earth, aimed at either destroying the asteroid, before it gets close to the Earth, or diverting the asteroid from the current trajectory to another trajectory that remove it from the Earth.

The orbit of the projectile P drawn to scale in the Fig. 6.1. Point E is the Earth and the focal point F_1 of the projectile orbit. The positions S and A of the projectile correspond respectively to the moments of launching from the satellite t_0 and intercepting the asteroid t.

It is known that r = 30010.88 km, $\Delta\theta = 46°$.

By measurements on the figures and calculations:

6.1. Find the elements of the transfer elliptical orbit of the projectile: semi-major axis a; semi-minor axis b; eccentricity e; distance to Perigee r_{min}, distance to Apogee r_{min}.

6.2. Find the orbital period of the projectile around the Earth T, if the projectile missed the asteroid interception.

6.3. Find the duration $\Delta t = t - t_0$ of the projectile's movement from point S to point A.

6.4α. Find the distance D_{SA} between points S and A, and the path L_{SA} travelled by the projectile since its launch from the satellite S until its meeting with the asteroid A.

6.4β. Find the elements of velocity vector (direction and value) of the projectile relative to the Earth, at the time of its release from the circumterrestrial satellite, $\vec{v}_{ellipse} = \vec{v}_0$, so that the way of the projectile from point S to point A would be the required ellipse.

6.5β. Find the velocity of the projectile $\vec{v}$, direction and value, at moment of its contact with the asteroid in point A.

6.6β. It is known that the second focal point F_2 of the ellipse is located on the segment SA. By measurements in Fig. 6.2 only, find and plot its location.

αβ-7. Analemma. Analemma is a figure that obtained when marking positions in the sky of the celestial body on different days of the year, but at the same time (as measured by usual watch). In the case of observations the Sun from the Earth it is shaped like an irregular eight. This is due to effect of the equation of time and varying the declination of the Sun during the year.

You are provided with a separate sheet with photo taken yesterday evening from the top floor of the hotel in Piatra Neamt, exactly in the East direction. The scale of the photo is 60° × 86° degrees per the printed area of the page. You need to plot analemma on this paper with binding to the area.

For simplicity, consider this part of the sky flat, that is, all the horizontal lines of the celestial sphere are parallel to the axis X, and all lines directed to zenith are parallel to the axis Y.

Take into account that the signs in the values of the equation of time in the ephemeris are given according to "European" definition (see the graph of the equation of time near the table).

7.1. Calculate positions of the Sun at $6^{H}00^{M}$ of local mean solar time for an observer located in Piatra Neamt, at the dates for which data are given in Table 7. Display your calculations in your answer-book. Write the results in your answer-book in the form of a table.

7.2. On the paper with photo draw a line of celestial equator, label it with the sign "**equ**".

7.3. For those cases when the calculated position of the Sun falls into the frame (regardless of whether it is in the sky, under the horizon or blocked by the mountain), draw images of the Sun in all the calculated positions, write the corresponding dates near the images.

7.4. Calculate, at what local time (according to local time, the switch to winter time should not be taken into account) should we take the pictures to get such analemma.

7.5. Add today's position of the Sun to the analemma.

7.6. Draw today's position of ecliptic at the time corresponding to today's position of the Sun on the analemma. Label it as "**ecl**".

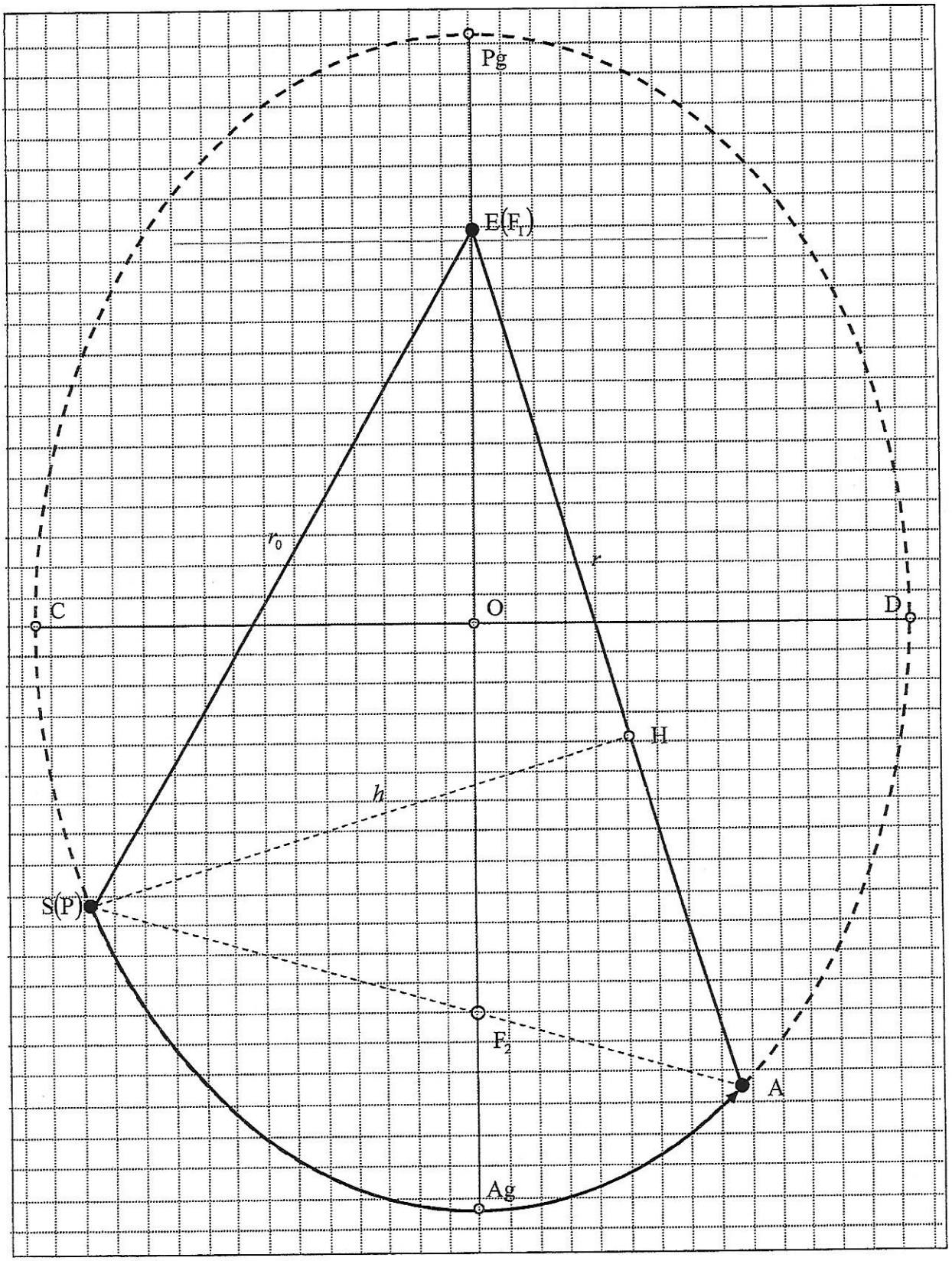


Fig 6.1

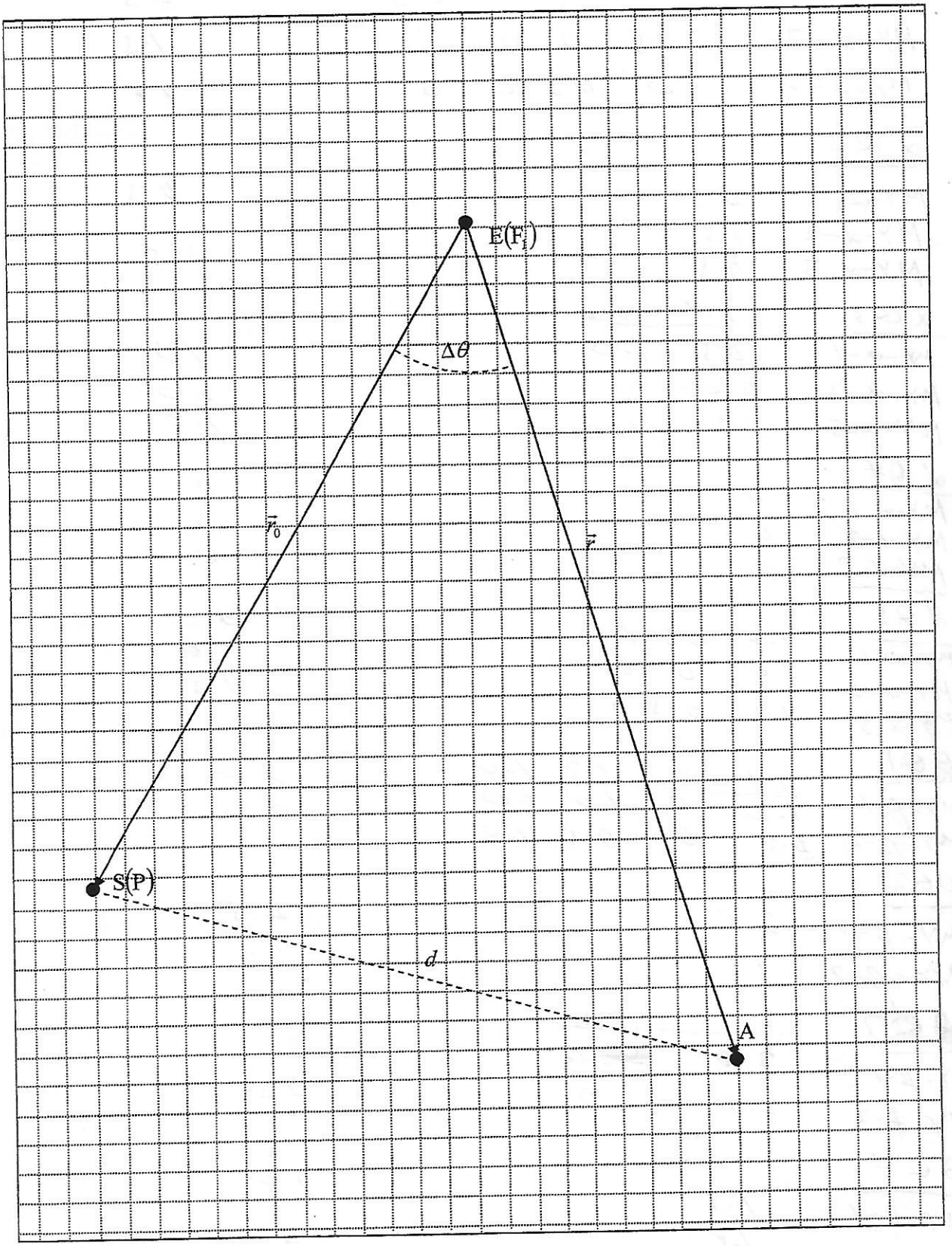


Fig. 2

АСТРОНОМИЧЕСКОЕ ОБЩЕСТВО

EURO-ASIAN ASTRONOMICAL SOCIETY

Round **Prac**

Group **αβ**

XXIV Международная астрономическая олимпиада
XXIV International Astronomy Olympiad

Румыния, Пьятра-Нямц 19-27. X. 2019 Piatra Neamt, Romania

язык / language	**Русский**
язык / language	**English**

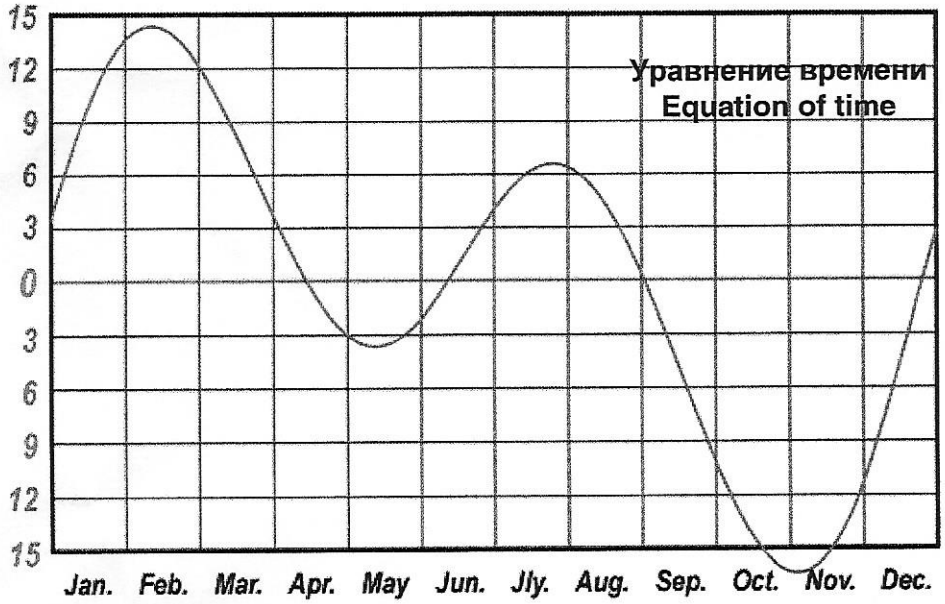
Практический тур
Таблица 7

Practical round
Table 7

Геоцентрические эфемериды Солнца : 2019
00:00 UTC (Всемирное координированное время)

Geocentric Ephemeris for the Sun : 2019
00:00 UTC (Coordinated Universal Time)

Дата (0 UT)	ЮД (2450000+)	Тек. ГЗВ (0 UT) ч м с	Уравнение времени м с	Прямое восхождение ч м с	Склонение ° ' "	Расстояние a.e.	Угл. диам. "
Date (0 UT)	JD (2450000+)	App. GST (0 UT) h m s	Equation of Time m s	Apparent R.A. h m s	Apparent Declination ° ' "	Distance a.u.	Ang. Diam. "
Jan 07	8490.5	07:05:06.0	+05:56.7	19 11 01.84	-22 25 54.3	0.983329	1951.8
Jan 22	8505.5	08:04:14.4	+11:22.0	20 15 35.51	-19 47 18.7	0.984073	1950.3
Feb 07	8521.5	09:07:19.3	+14:04.6	21 21 23.01	-15 27 46.1	0.986183	1946.2
Feb 22	8536.5	10:06:27.6	+13:34.1	22 20 00.79	-10 22 47.3	0.989022	1940.6
Mar 07	8549.5	10:57:42.8	+11:12.3	23 08 54.26	-05 28 29.5	0.992186	1934.4
Mar 22	8564.5	11:56:51.1	+07:06.9	00 03 57.08	+00 25 42.2	0.996178	1926.6
Apr 07	8580.5	12:59:56.0	+02:21.9	01 02 16.87	+06 38 12.2	1.000811	1917.7
Apr 22	8595.5	13:59:04.4	-01:19.6	01 57 43.67	+12 01 29.8	1.004979	1909.8
May 07	8610.5	14:58:12.7	-03:22.9	02 54 48.77	+16 40 22.7	1.008912	1902.3
May 22	8625.5	15:57:21.0	-03:22.8	03 53 57.15	+20 16 55.5	1.012148	1896.2
Jun 07	8641.5	17:00:25.9	-01:15.3	04 59 09.55	+22 41 57.5	1.014824	1891.2
Jun 22	8656.5	17:59:34.2	+01:50.9	06 01 24.18	+23 26 06.9	1.016266	1888.5
Jul 07	8671.5	18:58:42.6	+04:49.7	07 03 31.28	+22 37 59.4	1.016741	1887.7
Jul 22	8686.5	19:57:50.9	+06:26.3	08 04 16.28	+20 22 11.6	1.016076	1888.9
Aug 07	8702.5	21:00:55.8	+05:52.7	09 06 47.59	+16 33 26.5	1.014288	1892.2
Aug 22	8717.5	22:00:04.1	+03:04.5	10 03 07.62	+11 56 50.5	1.011617	1897.2
Sep 07	8733.5	23:03:09.0	-01:43.5	11 01 24.55	+06 15 20.4	1.007953	1904.1
Sep 22	8748.5	00:02:17.3	-07:02.1	11 55 14.26	+00 30 57.3	1.003962	1911.7
Oct 07	8763.5	01:01:25.7	-11:57.9	12 49 26.75	-05 18 07.4	0.999679	1919.9
Oct 22	8778.5	02:00:34.0	-15:26.3	13 45 06.57	-10 51 49.5	0.995418	1928.1
Nov 07	8794.5	03:03:38.9	-16:22.8	14 47 14.98	-16 07 11.2	0.991167	1936.4
Nov 22	8809.5	04:02:47.2	-14:06.9	15 48 39.21	-20 00 46.1	0.987822	1942.9
Dec 07	8824.5	05:01:55.5	-08:54.2	16 53 00.21	-22 32 36.3	0.985237	1948.0
Dec 22	8839.5	06:01:03.9	-01:50.8	17 59 12.00	-23 26 09.2	0.983717	1951.0



Coordinates / Координаты	Piatra Neamt / Пьятра-Нямц
λ (E / в.д.)	+26° 22′
φ (N / с.ш.)	+46° 56′
Timezone / Часовой пояс	UT+03

$G = 6.674 \cdot 10^{-11}\ N \cdot m^2/kg^2$

$M_E = 5.974 \cdot 10^{24}\ kg$